

## **HAZX - Part 2**

### **An Explosives Safety Risk Tool**

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### **ABSTRACT**

HAZX is an explosives safety software tool that can be used to assess the hazards and/or risks when Quantity-Distance (Q-D) safe separation distances are violated. Part 2 of the presentation focuses on the HAZX risk module which includes a GUI/GIS interface to simplify user inputs, spatial analyses and the display of results and reports. The risk tool is being initially developed using the algorithms and methods documented in DDESB's Technical Paper No. 14. The risk tool will eventually incorporate several new sub-models including: a) air blast consequences, b) roof and wall fragment penetration, c) physics-based fragment throw, d) human vulnerability, and e) uncertainty.

The HAZX risk tool's architecture and the development process used to meet the technical and software requirements for alternative software per DOD 6055.9-STD [1] are presented. The current HAZX risk tool is demonstrated on a complex explosives siting problem involving multiple PES's, each with multiple hazard divisions, and each affecting multiple ES's (buildings, vehicles, and people in the open).

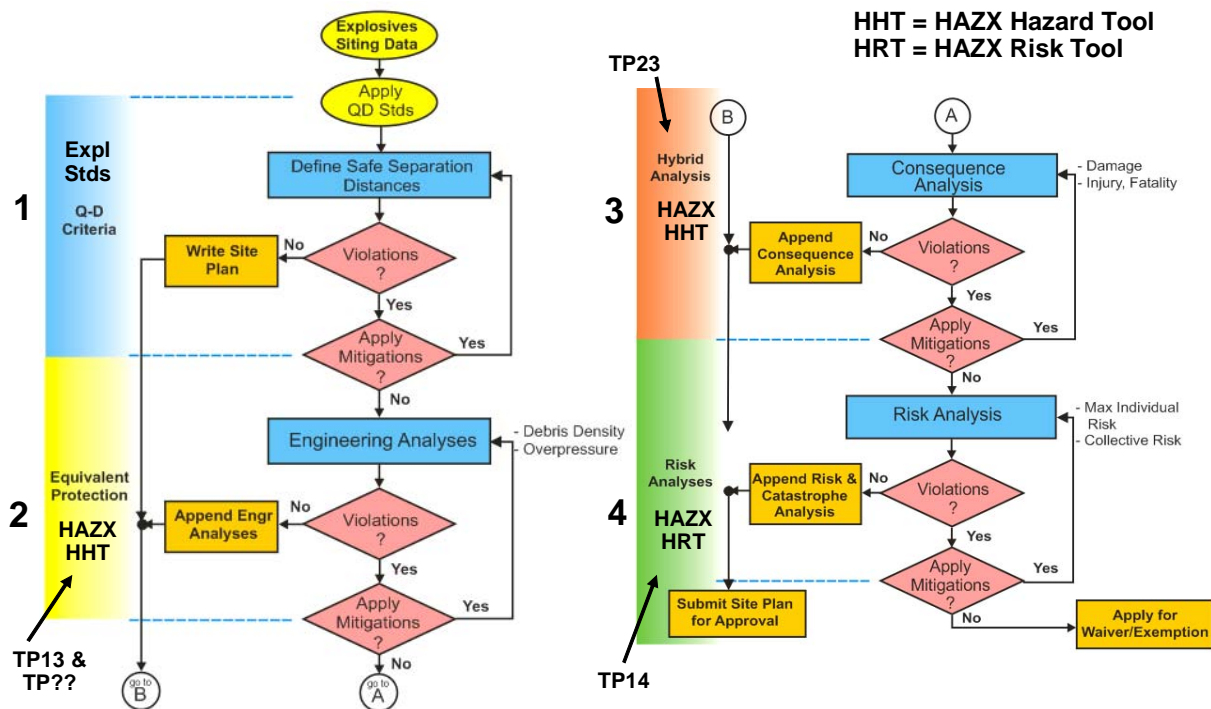
### **INTRODUCTION**

Figure 1 shows the four step process that the DOD Explosives Safety Board (DDESB) recommends for evaluating explosive hazards, consequences and risk in order to gain an explosives site plan approval. Note that all four steps do not have to be performed for approval; meeting the acceptance criteria for any of the four steps is sufficient. For example, if the explosives site plan is in conformance with the DOD Quantity-Distance (Q-D) criteria the other three steps need not be performed. Similarly, if a quantitative risk analysis (QRA) meets acceptable risk criteria the corresponding analysis can be used to gain site approval even if the Q-D safe separation distances are violated.

QRA's are compared to DDESB acceptable risk criteria for unrelated and related people exposed to explosive operations. The current DDESB acceptable risk criteria are based on: a) the annual maximum individual probability of fatality,  $P_f$ , and b) the annual collective fatality risk,  $E_f$  (expected number of fatalities). Table 1 summarizes the DDESB acceptable risk criteria.

The DDESB requires that a QRA be performed using approved methods and software. The DDESB has approved the risk methods and algorithms documented in Technical Paper No. 14, TP14 [2] which have been implemented in the SAFER software application [3]. This paper presents an overview of the HAZX risk tool (HRT) which is being developed to initially implement the TP14 methods and then to incorporate improved air blast, fragmentation, vulnerability and uncertainty models.

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**Figure 1. DDESB Process for Explosives Site Plan Approval.**

**Table 1. DDESB Acceptable Risk Criteria.**

Fatality Risk Metric	Exposure Group	DDESB Acceptable Risk (per year)
Maximum Individual	Unrelated	$1 \times 10^{-6}$
	Related	$1 \times 10^{-4}$
Collective	Unrelated	$1 \times 10^{-5}$
	Related	$1 \times 10^{-3}$

### HAZX Risk Tool (HRT)

A top level view of the HAZX architecture is shown in Figure 2. A Graphical User Interface (GUI) with an embedded Geographical Information System (GIS) acts as the interface between the HAZX Hazard Tool (HHT) and the HAZX Risk Tool (HRT). This paper focuses on the HRT while a companion paper (Reference [4]) describes the HHT. The HRT is being designed to initially perform a QRA according to the methods documented in TP14. As Figure 2 shows, new engineering models will then be incorporated into the HRT to improve the consideration of: a) uncertainty, b) air blast damage to buildings and windows, c) fragment/debris throw, d) roof and wall penetration, and e) human vulnerability. Figure 2 also shows that the HAZX HHT and HRT are being developed to interface with the DDESB's Explosive Safety Siting (ESS) software which automates the Q-D analysis process. HAZX will be able to link to the ESS geo-database to import registered maps as well as validated potential explosion source (PES) and exposed site (ES) attributes.

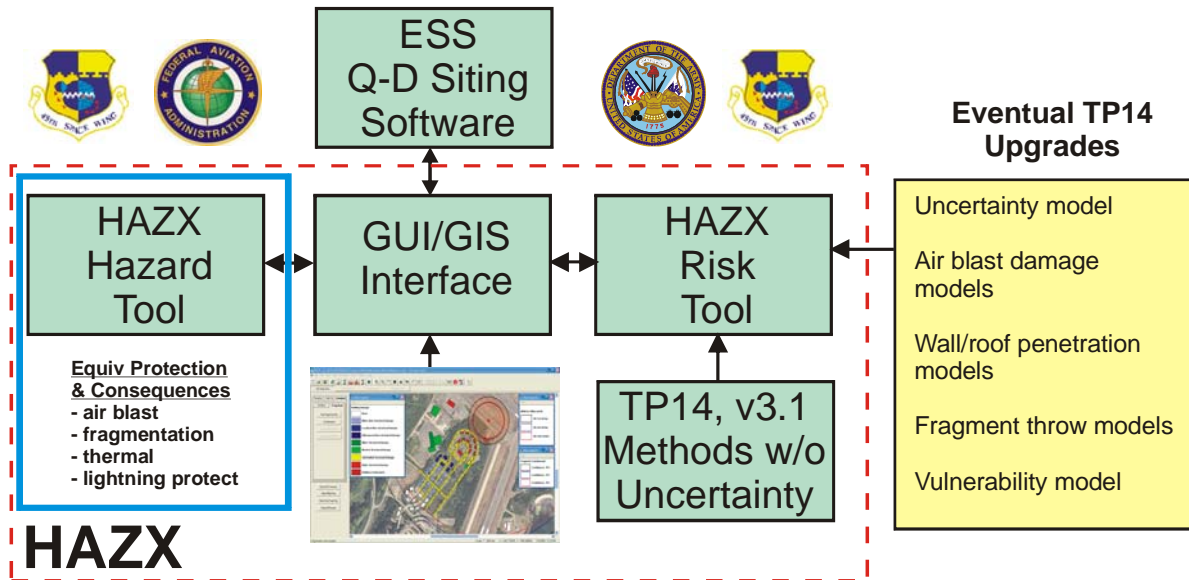


Figure 2. HAZX Architecture.

### HRT SOFTWARE DEVELOPMENT PROCESS

The latest DOD Explosives Safety Standard, 6055.9-STD, Chapter 17 on risk methods requires that an alternative risk tool meet the following requirements:

1. Follow the basic risk methodology as documented in DDESB TP14.
2. Follow a development process that will pass a software verification and validation (V&V) audit.
3. Insure that new engineering models satisfy the requirements of a technical peer review, and,
4. Document and justify the differences between TP14 risk results and those output by alternative models.

The requirements to gain DDESB approval for an alternative risk tool led to the following approach:

1. The HAZX Risk Tool (HRT) will be initially developed to implement the methods and algorithms of TP14. This approach satisfies the requirement to follow the TP14 risk methodology.
2. The HRT will be developed using a formal software (SW) development plan (SDP) which will include a: a) SW requirement specification (SRS), b) SE design description (SDD), c) SW test plan (STP), d) SW test report (STR), and e) SW technical and users manuals. This satisfies the V&V requirement.
3. A series of sample problems will be run and the results compared with the SAFER application to insure that the HRT is “duplicating” the results output by the approved software. This establishes the HRT as a reference application prior to incorporating new models.
4. The HRT version developed in 3) will then incorporate upgraded engineering models one-by-one so that differences with the original TP14 risk results can be isolated. This satisfies the requirement to justify and document differences and risk results.

### THE HRT

As discussed above the current HRT implements the latest methods and algorithms of DDESB TP14, Version 3 (Revision 4). A top level schematic of the HRT is shown in Figure 3. The HRT is driven by a GUI/GIS that is used to define all user inputs and display risk results. The GUI/GIS input screens have been designed to emulate those used by the SAFER application [3] when possible. The numerous

underlying data tables defined in TP14 have been encapsulated so modifications, additions and deletions do not affect the main source code. The GUI/GIS provides all inputs to the HRT in Extensible Markup Language (XML) format and writes out all results in XML; therefore, other GUIs can easily access the HRT if the need arises. The GUI/GIS used by the HRT (Figure 4) looks very similar to the one described in the HAZX 1 Hazard Tool companion paper and the reader is referred to that paper for additional details. For example, the process of registering a base map and drawing in PES's and ES's (buildings, roads and people in the open) is very similar to that used in the HAZX Hazard Tool (HHT). However, several paradigm shifts have been incorporated into the HRT GUI to greatly simplify the set up of complex TP14 risk problems; these shifts are described in the sample problem section below.

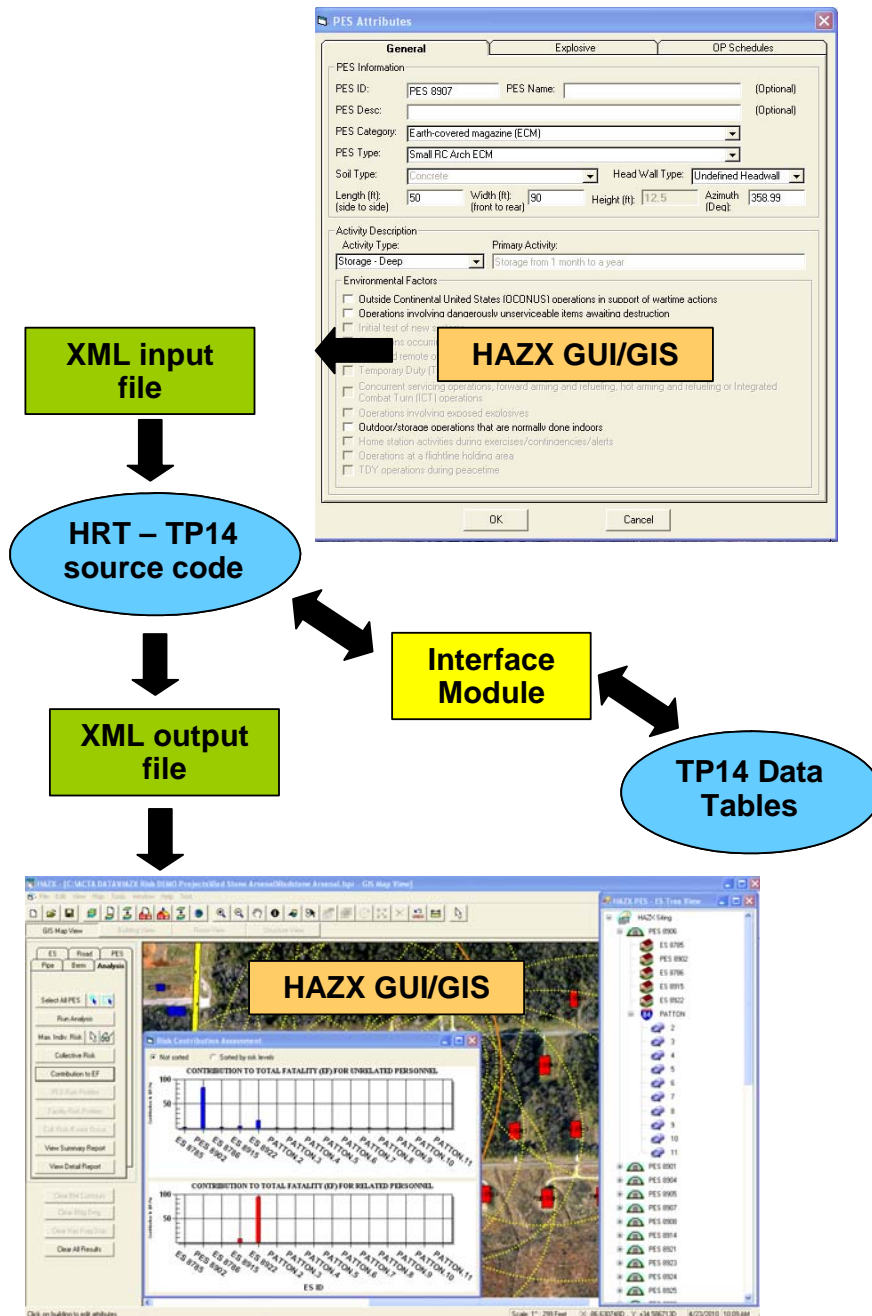
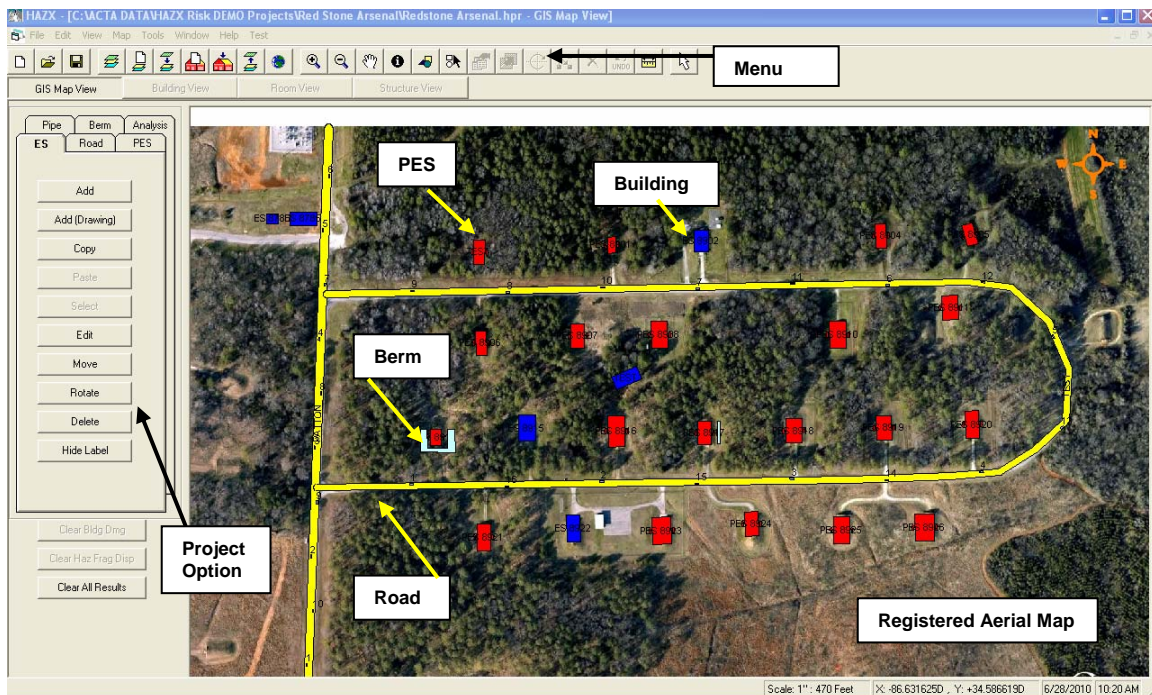


Figure 3. Schematic of TP14 Implementation in the HRT.





**Figure 4. Example of Problem Opened Up in the HAZX Risk Tool (HRT).**

### **SETTING UP A COMPLEX RISK PROBLEM**

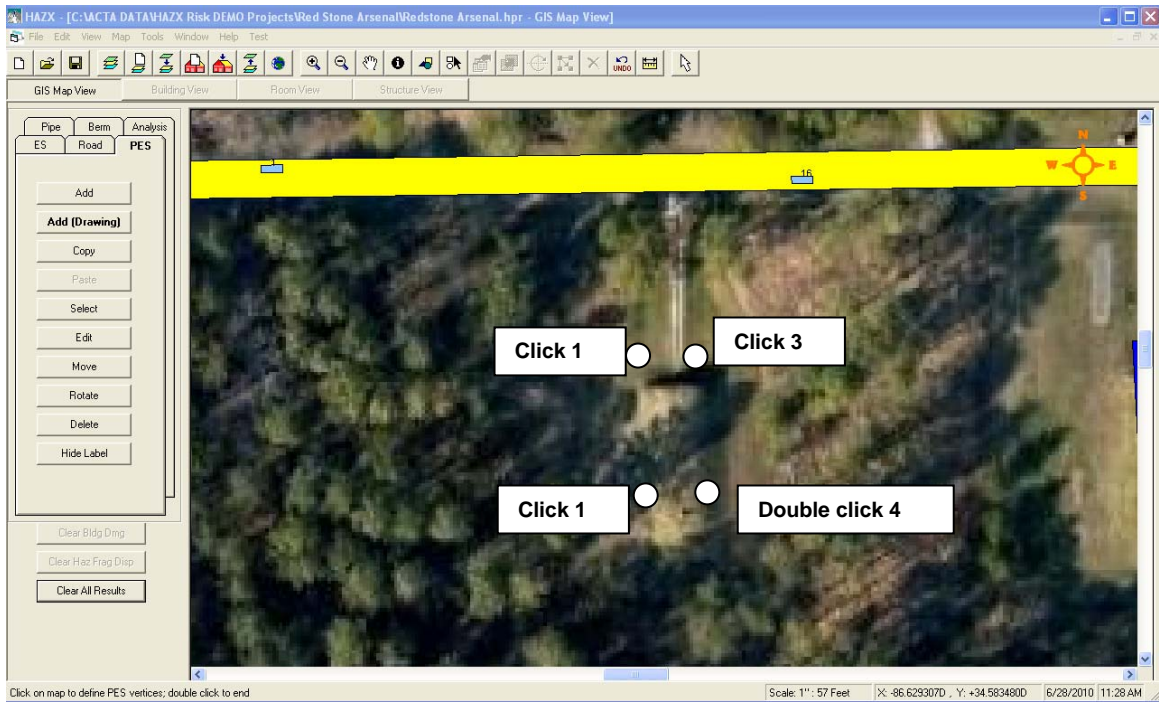
The HAZX Risk Tool (HRT) is demonstrated by setting up and performing a hypothetical TP14 risk analysis for a situation involving multiple PES's (each containing multiple hazard divisions) and multiple ES's as shown in Figure 4. In the figure PES's are shown in red, buildings in blue, roads in yellow and a barrier/berm in cyan.

#### **POTENTIAL EXPLOSION SOURCE**

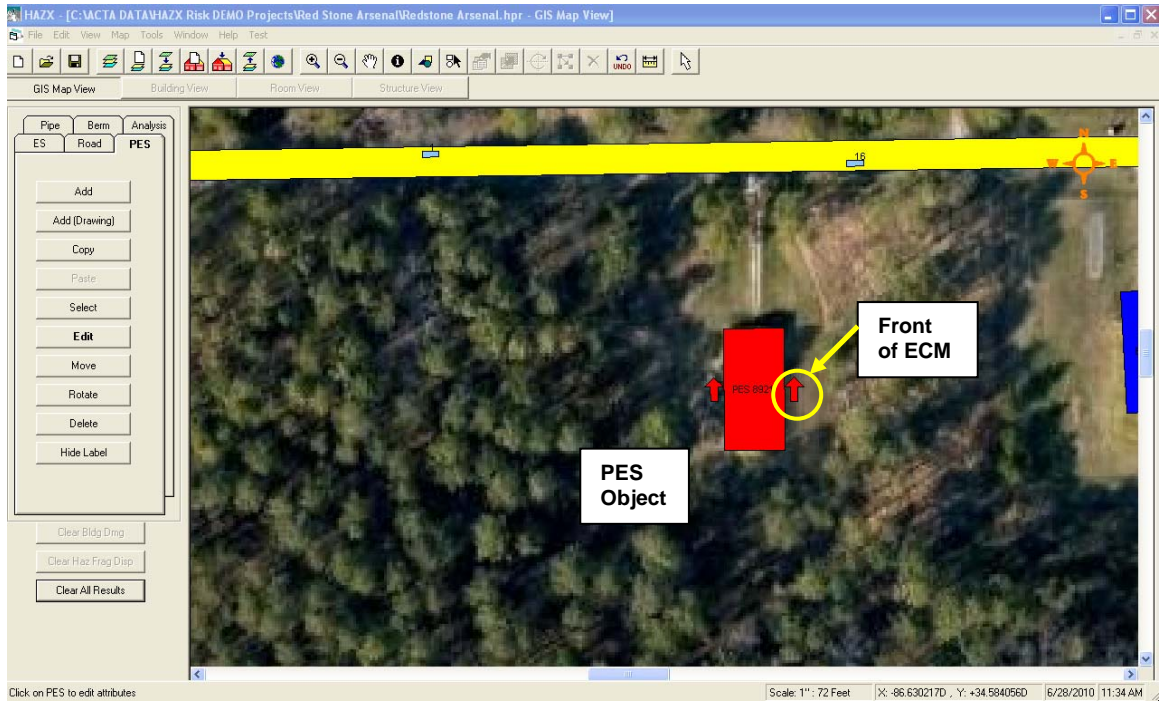
A user draws a PES as shown in Figure 5 and Figure 6 by clicking along the outline of the PES on the registered base map and double clicking on the final location. Note that the user can use the GIS to define the front side of an earth covered magazine (ECM) or hardened aircraft shelter (HAS) (this metric is used in TP14 risk calculations). Figure 7 shows the three screens for entering the PES attributes. The first two look very similar to SAFER screens. However, a paradigm shift was made for entering the PES hazard division data. When multiple hazard divisions are defined, the user can have the HRT calculate the associated Inhabited Building Distance (IBD) for each HD and determine the controlling HD which is subsequently used in a TP14 risk analysis. A second paradigm shift was made in order to calculate the percent time each ES is exposed to a PES. The user enters the operating schedule of the PES by clicking on how many work shifts are performed and for how many days, weeks and months of the year. (The user will also fill in a calendar to define the exposure of population groups at each ES and the HRT will calculate the PES-ES exposure time automatically). Also note that a PES (along with its attributes) can be copied and pasted to another location and edited to simplify the definition of similar PES's.

#### **EXPOSED SITES**

The HRT GUI/GIS allows a user to draw in buildings, roads and locations of people in the open. Buildings are drawn in the same manner as a PES by clicking on the corners of the base map image and double clicking on the final location (Figure 8). The building attribute screens are shown in Figure 7. The first attribute screen used for defining the building's construction and window types is similar to that of SAFER. The population data screen, however, represents a paradigm shift as a calendar is used to define the exposure of multiple unrelated and/or related population groups in a manner to that used for PES's. Just like for PES's, Building ES's can be copied and pasted to another location.



**Figure 5. Entering a PES.**



**Figure 6. PES Overlaid on Base Map.**



The figure displays three overlapping windows of the 'PES Attributes' dialog box, each showing a different tab: General, Explosive, and OP Schedules.

**General Tab (Top Left):** Contains fields for PES ID (PES 8921), PES Name, PES Desc, PES Category (Earth-covered magazine (ECM)), PES Type (Small RC Arch ECM), Soil Type (Concrete), Head Wall Type, Length (ft) (50), Width (ft) (100), Height (ft) (12.5), Activity Type (Training), Primary Activity (Training in the use of A&E), and a list of Environmental Factors with checkboxes.

**Explosive Tab (Top Right):** Contains fields for Hazard Division Inputs, Hazard Division (1.2.2), Weapon Type (MK2 (40 mm) projectile), Weapon Desc (Robust or thick-skinned 40 mm projectile), Sited NEWQD (2672), Expected NEWQD (2672), IBD for this Hazard Division (298 (ft)), Number of ISO Containers, For Sited Value (0), For Expected Value (0), Compatibility Group (D), Event Probability (0.000003), Baseline Hazard Division (1.2.2), and IBD (298 (ft)).

**OP Schedules Tab (Bottom):** Contains fields for Weekly Activities (24/7 event, Day Shift Hours (7.2), Swing Shift Hours (0), Graveyard Shift Hours (0), Days per Week (5)) and Annual Schedules (Whole year event, January, April, July, October, February, November, March, December), and Annual Operating Hours (159.43).

Annotations highlight specific features: 'PES general attribute screen' points to the General tab, 'PES hazard division screen' points to the Explosive tab, and 'Ability to automatically calculate IBD for each HD' points to the IBD field in the Explosive tab. 'Calendar paradigm used to define PES operating schedule and related personnel' points to the Annual Schedules section in the OP Schedules tab.

Figure 7. PES Attribute Dialog Boxes.



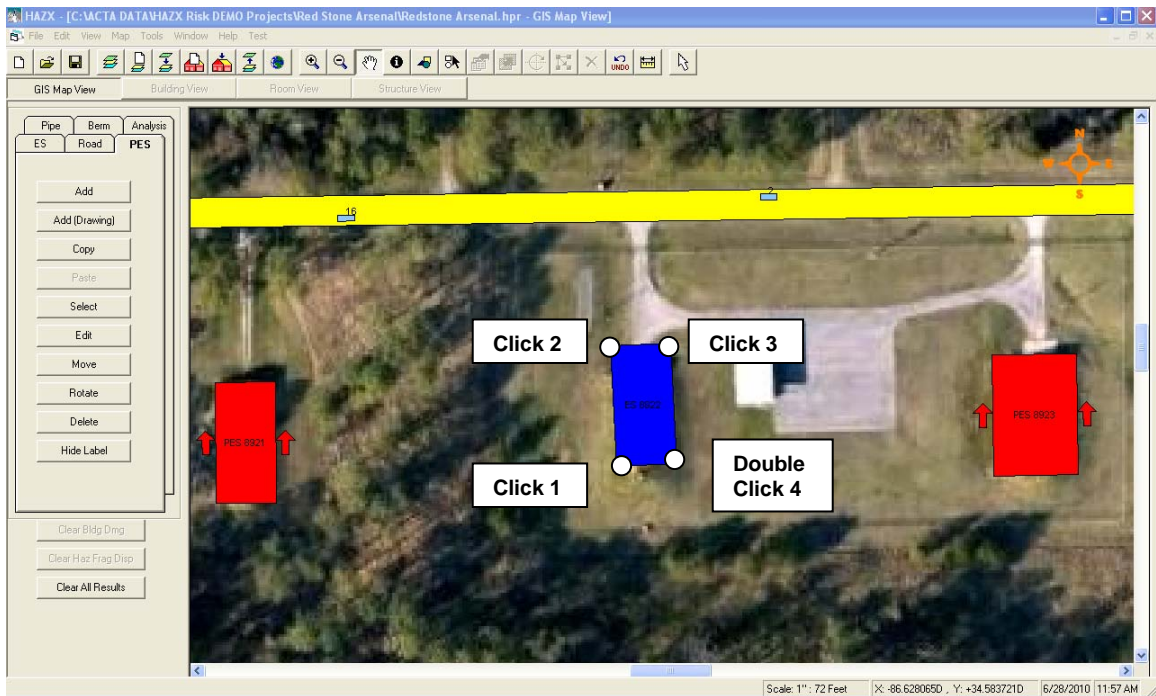


Figure 8. HRT Building Object.

**Building Attributes**

**Building Information**

Bldg ID: ES 8922 Bldg Name: (Optional)

Bldg Desc: (Optional)

Bldg Category: Reinforced concrete Window Type: None

Bldg Type: Small Reinforced Concrete (Office/Commercial)

Roof Type: 4 in reinforced concrete % Glass: 0

Length (Feet): 50 (distance from side to side)

Width (Feet): 100 (distance from front to rear)

Height (Feet): 12

Azimuth (Deg): 357 (from north to the bldg facing)

Plan Area: 5000 (Sq. Ft.) Set Front Wall

(front wall designation not used by TP-14)

**Exposure**

Related PES

- ☐ PES 8901
- ☐ PES 8904
- ☐ PES 8905
- ☐ PES 8906
- ☐ PES 8907
- ☒ PES 8908
- ☐ PES 8910
- ☐ PES 8911
- ☐ PES 8914
- ☐ PES 8916
- ☐ PES 8917
- ☐ PES 8918
- ☐ PES 8919
- ☐ PES 8920
- ☐ PES 8921
- ☐ PES 8923

**Building Attributes**

**Building Information**

**Exposure**

Exposure Groups:

Group	Description	Type	People	Daily Shift	Hrs/Shift	Days/Wk	Yearly	Ann Hours				
1	Related Personnel	Related	6	Whole Day	24	2	<input type="checkbox"/>	212.6				
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

OK Cancel

Figure 9. Building Attribute Screens.

The HRT GUI/GIS allows a user to draw in a road segment by clicking along the base map image and double clicking on the ending location as shown in Figure 10. The road segment attributes screens are shown in Figure 11. The user can select the road to be one-way or two-way and then specify the a) vehicle speed, b) number of people per vehicle, c) number of vehicle per hour, and d) number of hours, days and weeks per year. Finally, the user enters the vehicle spacing along the road segment at which risk calculations will be performed (the shorter the spacing the more accurate the risk calculations). Based on these entries the HRT places a vehicle at the requested spacing and calculates the average annual exposure of the occupants. The second screen allows the user to enter the vehicle dimensions (a sedan is the default) and the window type (small tempered is the default but TP14 does not consider fatalities due to car window breakage so the percent glass default is zero). Future model upgrades will consider vehicle window consequences.

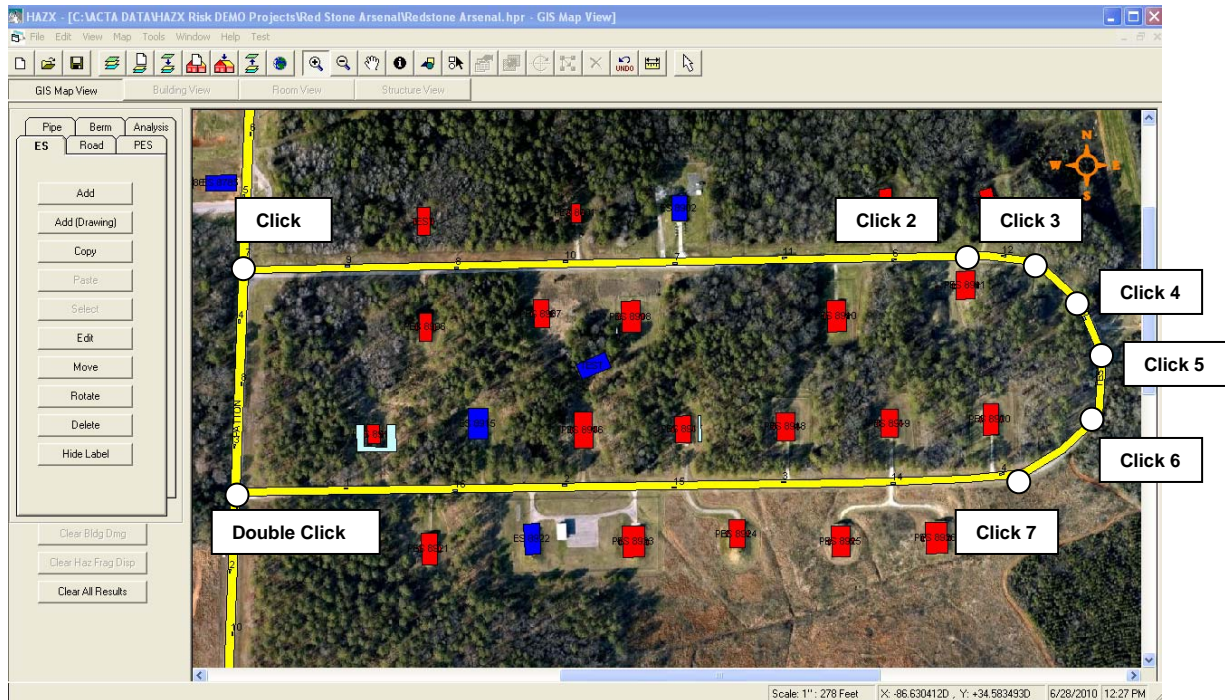


Figure 10. Drawing in a Road Segment.

## BARRIERS

The HRT GUI/GIS can also be used to draw in barriers that can block low-flying fragment and debris thrown towards an ES due to the break up of a PES. The user draws in a barrier just as he would a building or a PES except that a barrier can be a polygon (Figure 12). After drawing in the barrier the user enters its height via a dialog box. During a risk analysis, The GIS performs a spatial analysis using TP14's simple line-of-sight logic to determine in which direction fragments/debris will be blocked and which ES's be protected.

## **RUNNING A COMPLEX RISK PROBLEM**

### QUANTITY-DISTANCE ANALYSIS

Once the PES, ES and barrier data have been entered the "Analysis" tab can be selected from the Project Option Tabs as shown in Figure 13. This allows the user to perform several types of analyses. The user can select a) all PES's for an analysis, b) a single PES, or c) a PES subset. Once the PES(s) are selected the user can elect to perform a Q-D IBD analysis using the ESS QD engine. Figure 13 shows the controlling Q-D IBD arcs for two PES's (an ECM with the IBD controlled by HD 1.2.1 and an aboveground operating building with IBD controlled by HD 1.1).

**Road Segment Attributes**

Road Segment				Vehicle					
Road Seg ID:	TEST	Name: (Optional)		Desc: (Optional)					
Road Width (ft):	25	Seg. Length (mi):	1.120875	<input type="radio"/> 1 - Way Road <input checked="" type="radio"/> 2 - Way Road					
Risk Calc Interval (ft):	700	# of Vehicles/Segment:	16	( for road segment risk calculation resolution only )					
Exposure Groups:				Add New Group					
Group	Description	Daily Shift	Avg MPH	Peop/Veh	Veh/Hr	Hrs/Shift	Days/Wk	Yearly	Ann Hours
+ 1	test	Whole Day	25	2	2	24	7	<input checked="" type="checkbox"/>	8760

Vehicle Length: 14 (ft)    Width (ft): 5 (ft)    Height (ft): 5 (ft)

Window Type:     % Glass:

OK    Cancel

Figure 11. Road Segment Attributes.

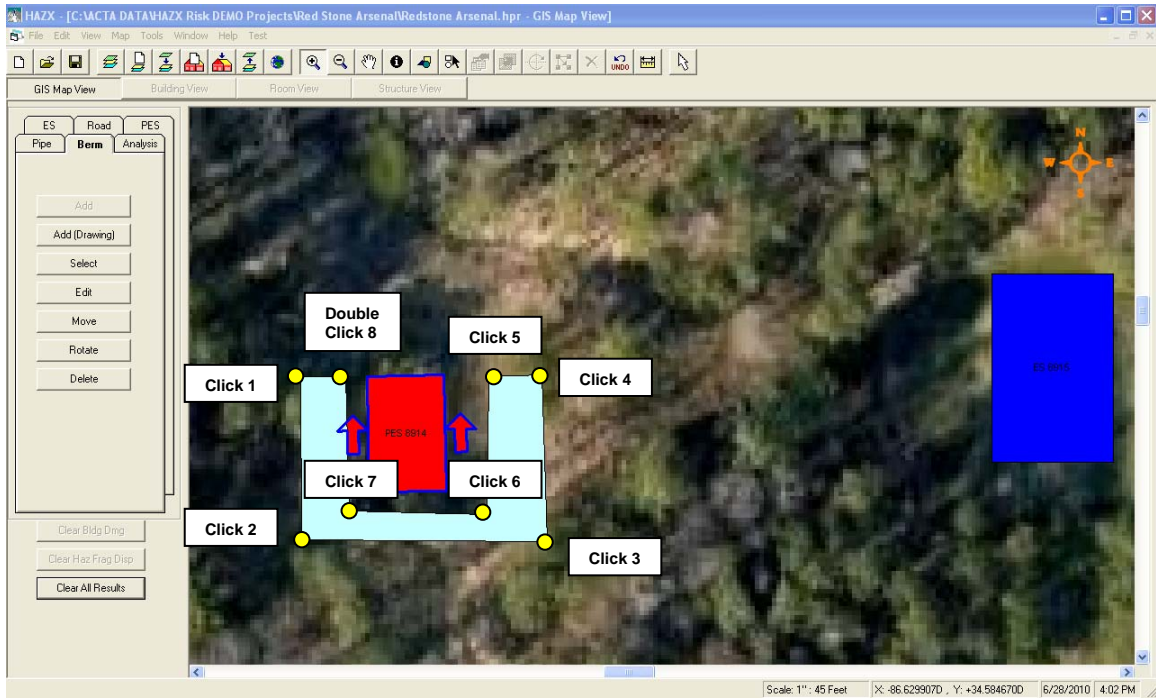
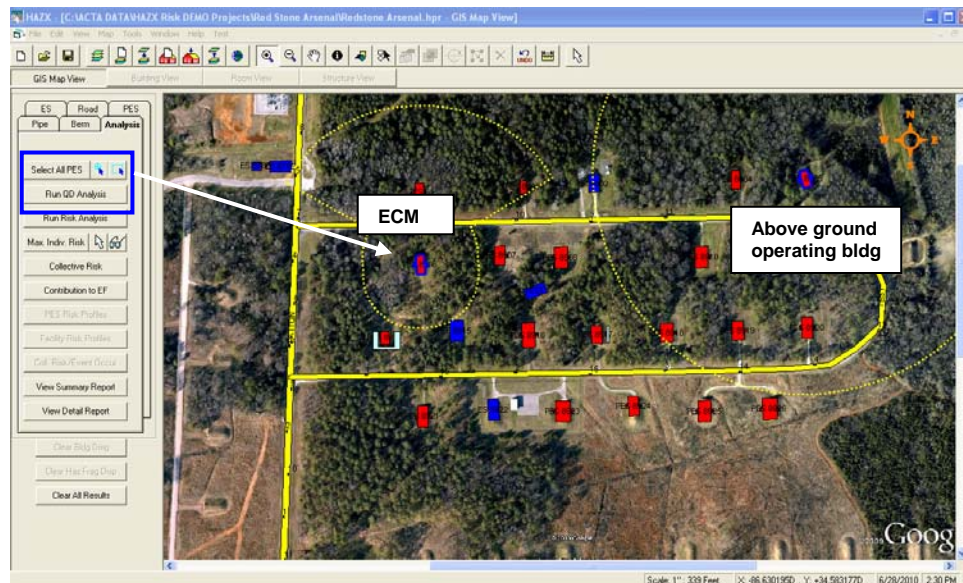


Figure 12. Drawing in a Barrier.





**Figure 13. Controlling IBD Arcs for Two PES's storing Multiple Hazard Divisions.**

## RISK ANALYSES

One of the most powerful capabilities built into the HRT and its GUI/GIS is the automation of the risk analyses. The TP14 risk methodology requires that a PES-ES analysis tree be developed. The PES-ES tree defines which PES's should be included in the risk analysis and which ES's are affected by each PES. The risk analysis loops over the each PES and calculates the risk to the population groups in each ES it affects. When the calculations for a PES and its ES's are completed the next PES and its ES's are considered. When all PES's have been evaluated, the maximum individual and group risks are aggregated and compared to risk acceptance criteria. In order to compare calculated risk results with acceptance criteria, the DDESB requires that a "PES Siting" analysis be performed. A PES Siting analysis uses the following rules to develop the PES-ES Tree:

1. The ES's affected by each PES are determined as follows:
  - a. The controlling HD IBD Q-D arc (the largest IBD for any hazard division) is computed.
  - b. The controlling HD distance to a maximum individual probability of fatality of  $P_f < 1.0E-08$  for people in the open is calculated.
  - c. The ES's within the union of the distances computed in a) and b) are the ones that will be affected by the PES.
2. The same procedure is performed for all other PES's.
3. The PES-ES Tree is constructed based on 1) and 2).

The HRT automates the above process by using a GIS spatial analysis tool. The complicated PES-ES tree generated automatically for the example problem is shown in Figure 14.

Once the PES-ES Tree is generated, the HRT performs a TP14 risk analysis to compute the maximum individual and group risk. The HRT can display numerous risk results to assist the user in understanding the solution. The summary result button compares the computed risk metrics to the DDESB acceptable risk criteria as shown in Table 2. The user can click on the "Max Indiv Risk" button to display the maximum individual risk for each ES. Clicking on the "Eyeglass" button displays which PES-ES pairs contribute the most to the maximum individual risk. The "Collective Risk" button displays the contribution of each PES to the overall collective risk (expected number of fatalities). Finally, the "Contribution to Ef" button displays the relative contribution of each ES to the total collective risk, Ef. Each one of these display helps the user better understand which PES operations and ES population groups drive the risk results and assist in evaluating potential mitigations.



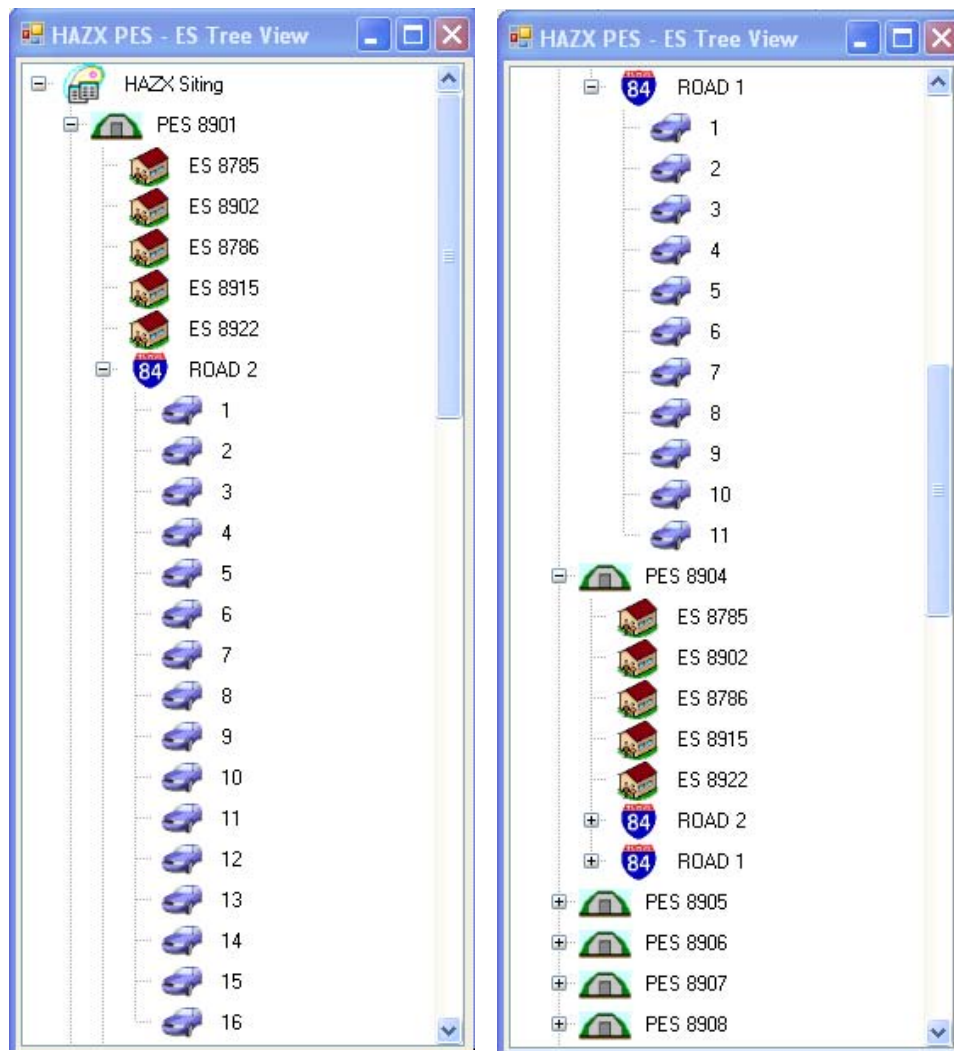


Figure 14. Partial PES-ES Tree for Example Problem.

Table 2. HRT Risk Results Compared to DDESB Acceptance Criteria

Risk Metric	Population Group	HAZX Risk (per year)	Acceptance Criteria (per year)
Max Individual Fatality	Unrelated	4.27E-05 (ROAD 2,14)	1.00E-06
	Related	3.02E-07 (ES 8915)	1.00E-04
Group Fatality	Unrelated	2.19E-05	1.00E-05
	Related	1.21E-06	1.00E-03

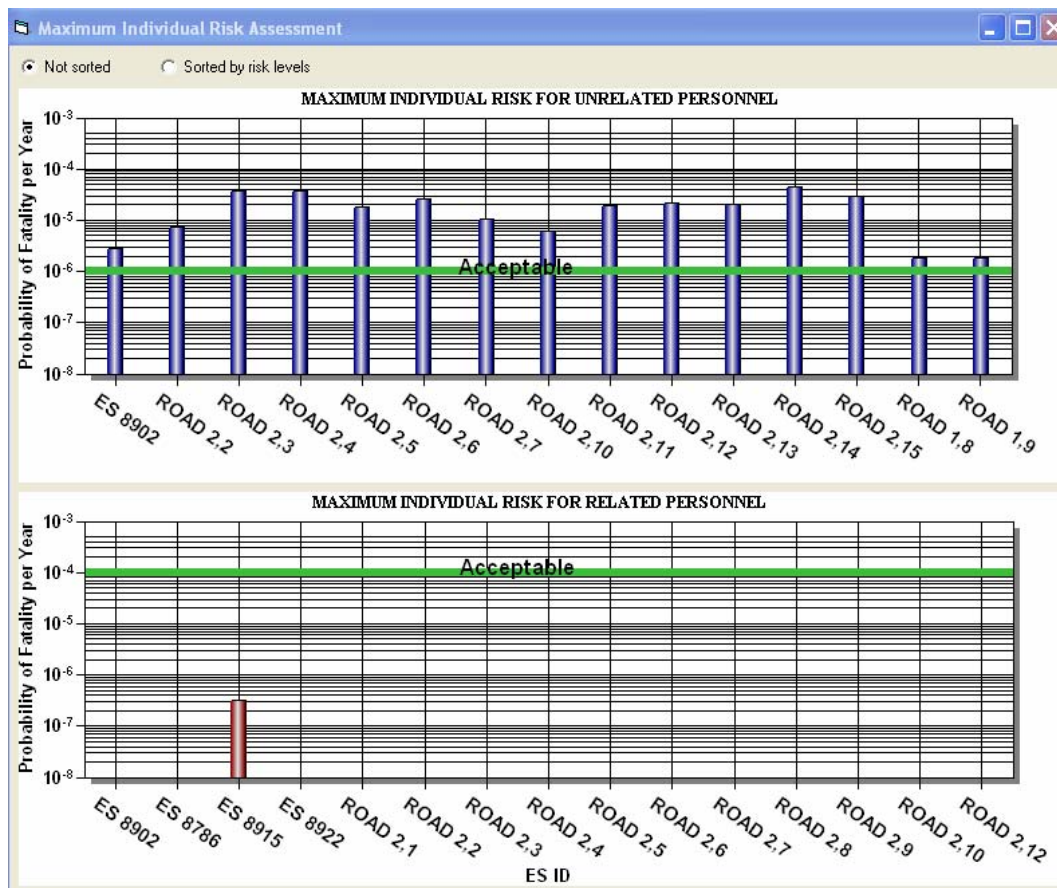


Figure 15. Maximum Individual Risk Display.

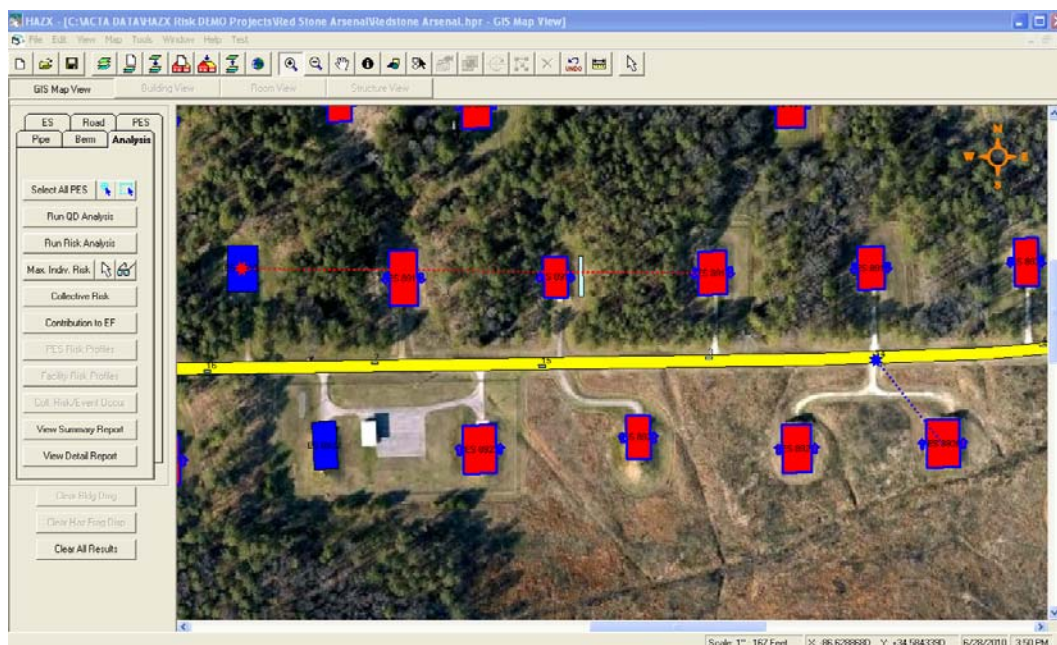


Figure 16. PES-ES Pairs causing greatest Contribution to Individual Risk (blue = unrelated, red = related).

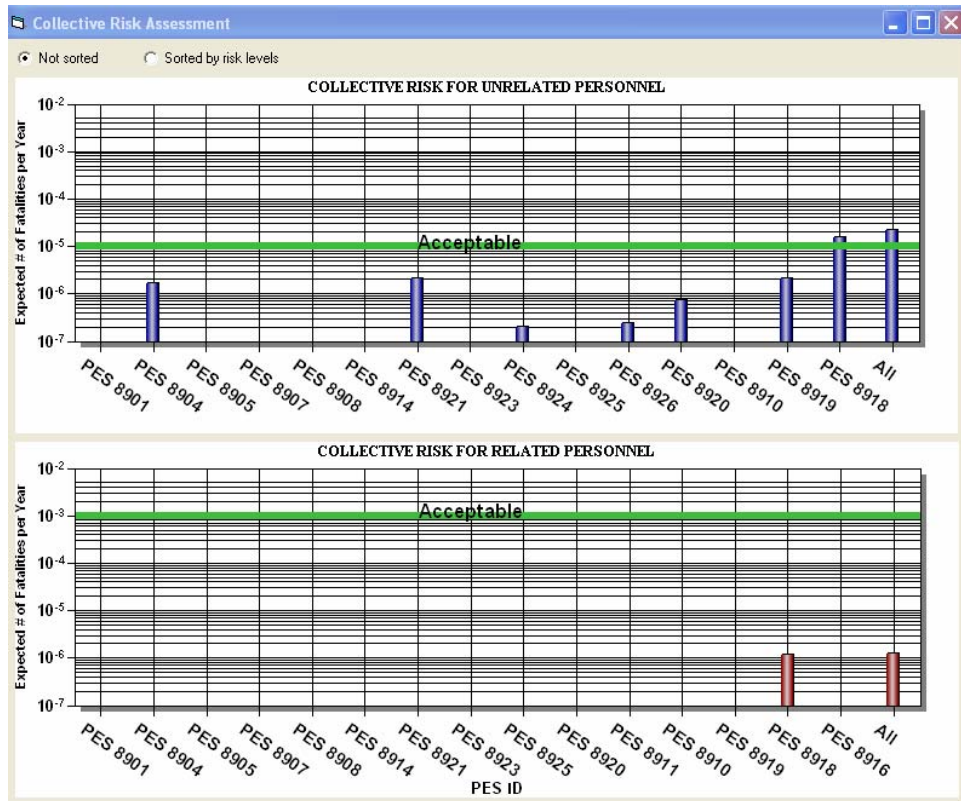


Figure 17. Collective Risk Display.

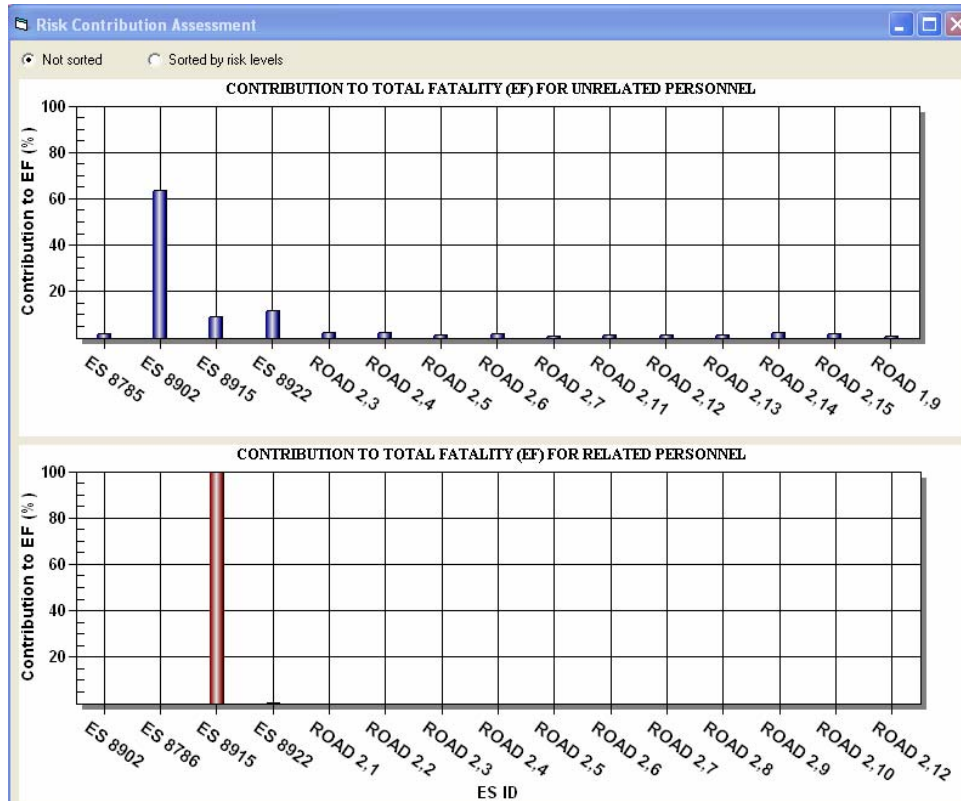


Figure 18. Relative Contribution of ES's to Overall Collective Risk.

## **CONCLUSIONS**

This paper summarizes the development and capabilities of the HAZX Risk Tool (HRT). Combined with a robust GUI/GIS, the HRT simplifies the performance of DDESB Technical Paper No. 14 quantitative risk analyses. A complex explosives siting problem was presented to demonstrate how the HRT is used to simplify the entry of: a) PES's and their attributes, b) ES's and their attributes, and c) barriers. The HRT was then used to perform a "PES Siting" risk analysis that included the automatic generation of the PES-ES tree. The architecture of the HRT and its GUI/GIS allow a user to easily perform sensitivity or "what-if" analyses; PES's and ES's can be copied/pasted, their locations and attributes modified, a new PES-ES tree automatically generated and the risk analysis re-run.

The HRT is being developed for approval as an alternative DDESB risk tool and at present is still considered prototype software. Extensive testing and the addition of a new uncertainty model is scheduled for the coming year at which time DDESB approval will be sought. After initial approval, several of the underlying engineering models will be upgraded to include: a) 3D air blast consequence model, b) physics-based fragment/debris throw models, c) wall and roof penetration models, and d) human vulnerability models.

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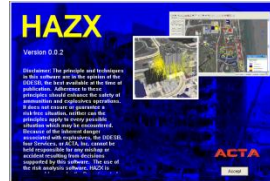
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- [3] SAFER – Version 3.1, "User's Reference for the Safety Assessment for Explosives Risk Software", DDESB Technical Paper No. 19, 21 July 2009.
- [4] Chrostowski, J.D, et. al. "HAZX – Part 1, An Explosives Hazard Assessment Tool", presented at the 2010 DDESB Explosives Safety Seminar, July 2010.



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## An Explosives Risk Assessment Tool



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# Outline

- **Goals & Objectives**
- **Explosives Safety Analysis Process**
- **HAZX Architecture**
- **HAZX Risk Tool (HRT)**
  - *Software Development Process*
  - *Software Documentation*
  - *Development Status*
- **Demonstration Problem**
- **Conclusions**



# Goals & Objectives

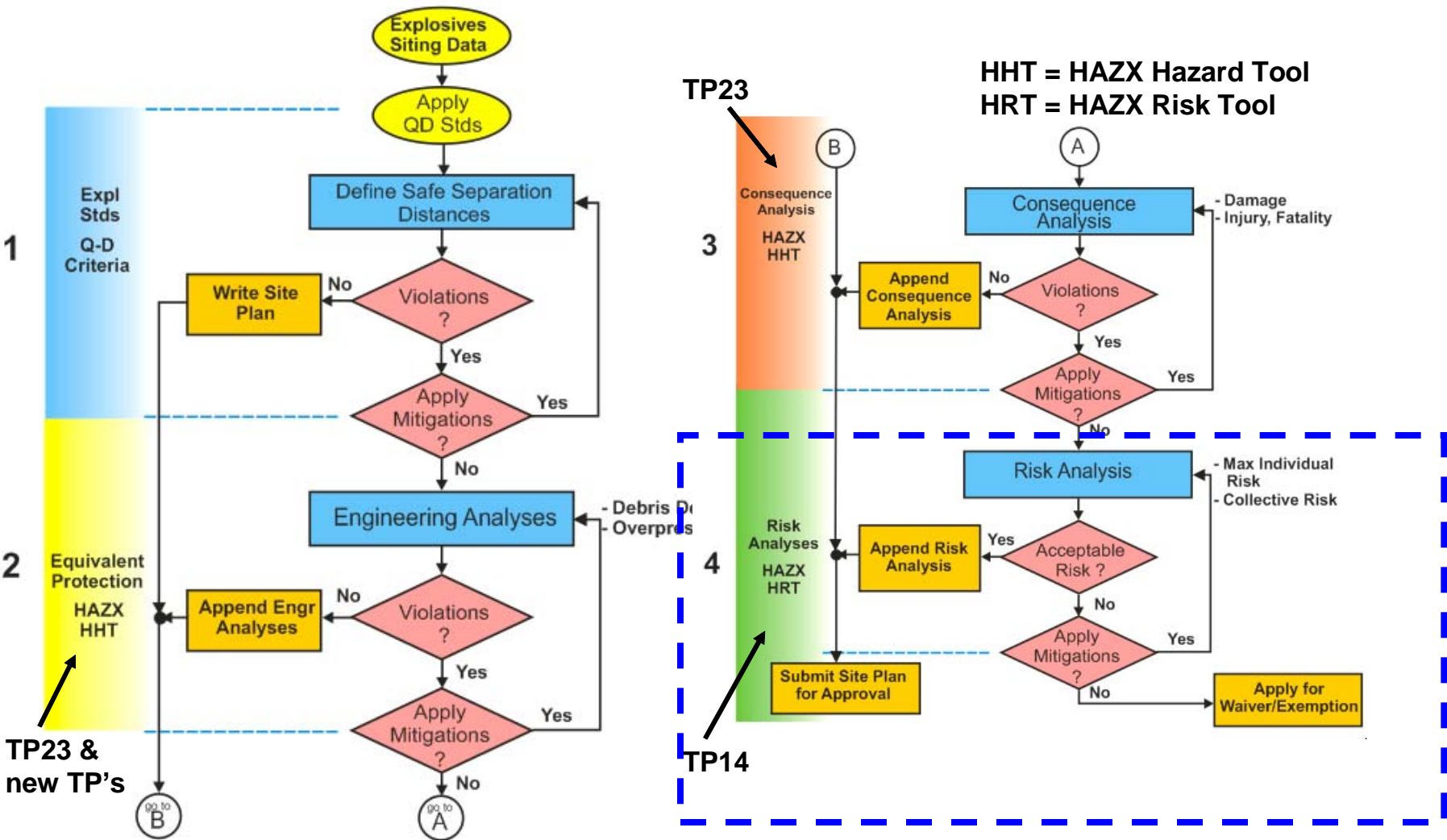
- Ultimate goal is to provide an alternative (and upgraded) conventional weapons explosives risk assessment tool that can be approved for use by the DDESB and also meet end-user needs
- Objectives to meet this goal are:
  - *Make the implementation of the TP14 risk methods easy to use*
  - *Eventually incorporate upgraded assessment models*
    - Uncertainty Model
    - Air Blast Effects
    - Fragmentation and Debris Throw
    - Thermal Effects
    - Vulnerability Models
- Constraints on the SW:
  - *Conform to the 6055.9-STD requirements for approving alternative risk-based software*



# Explosives Safety Analysis Process

## and

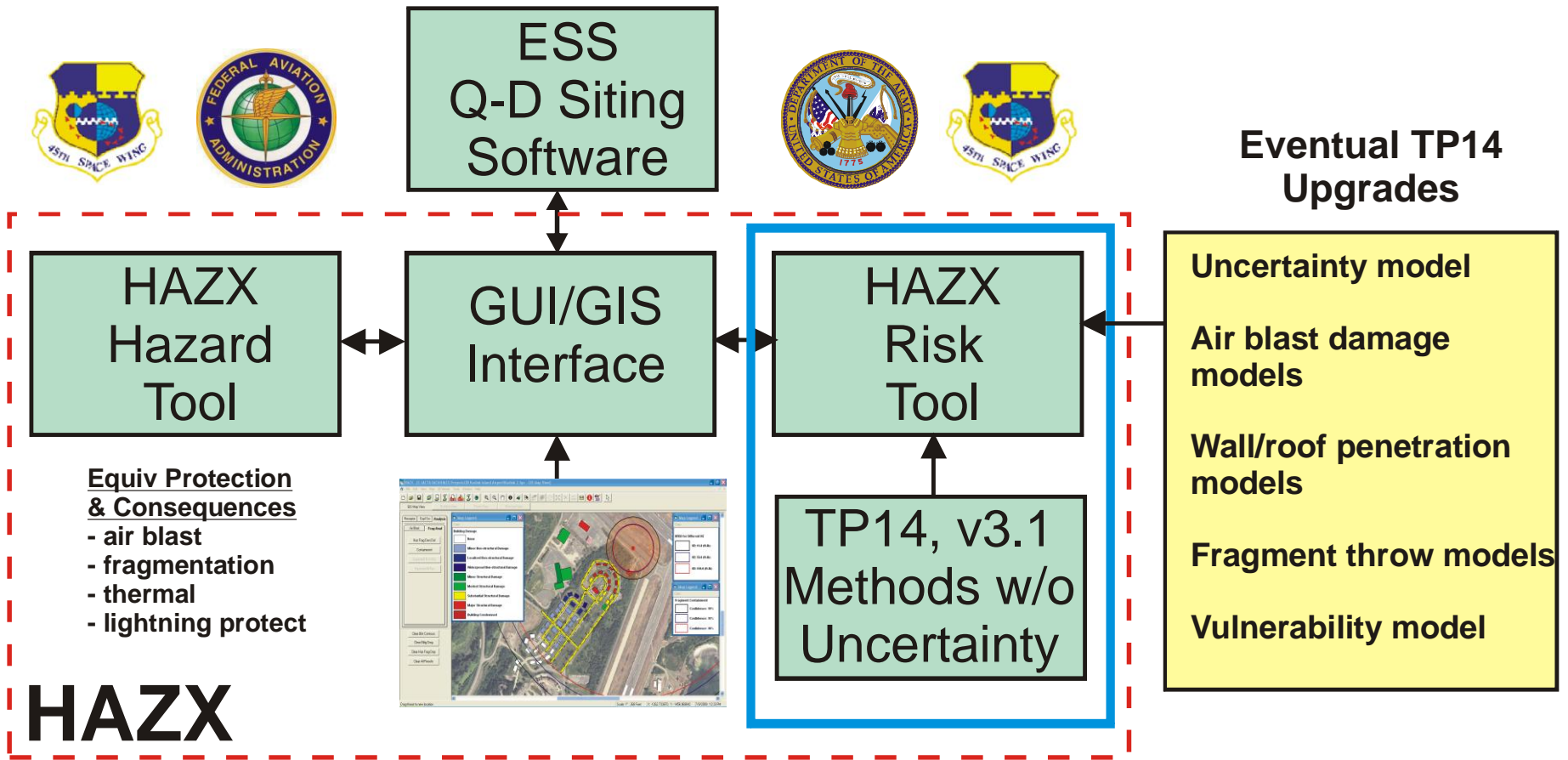
## The Long Term Vision for HAZX Risk Tool







# HAZX Architecture





# DDESB Alternative Risk SW Requirments

- The following paragraph is in the latest release of 6055.9-STD... requiring V&V for risk-based SW (noting that the “I” for Independent V&V has been removed from previous drafts)*

## ***C17.7. EQUIVALENT RISK-BASED ANALYSIS TOOL***

***An equivalent risk-based analysis tool for use in risk-based siting must meet these requirements to be approved by the DDESB:***

***C17.7.1. Address all applicable aspects of the approved risk-based model. (See Reference (au).)***

***C17.7.2. Document all data sources used to develop the algorithms used in the model.***

***C17.7.3. Provide software validation and verification results to the DDESB for an assessment and have the software certified by the DoD Information Technology Security Certification and Accreditation Process.***

***C17.7.4. Provide the results of a peer review of the model to the DDESB for an assessment.***



# HAZX Risk Tool Development Process

- Develop the HRT under a formal SW development process (*MIL-STD or IEEE standards*)
  - *Allows for SW verification and validation (V&V)*
- Initially implement the risk-based methods and algorithms in DDESB TP14
  - *Meets requirement for addressing all applicable aspects of approved risk model*
- Run a series of test cases to compare HRT results with SAFER TP14 implementation
  - *Justify & document any differences*
- Add upgraded risk models one-by-one to justify differences between legacy models
  - *Satisfies requirement for peer review and new vs. legacy justification*



# HAZX HRT Formal SW Documentation

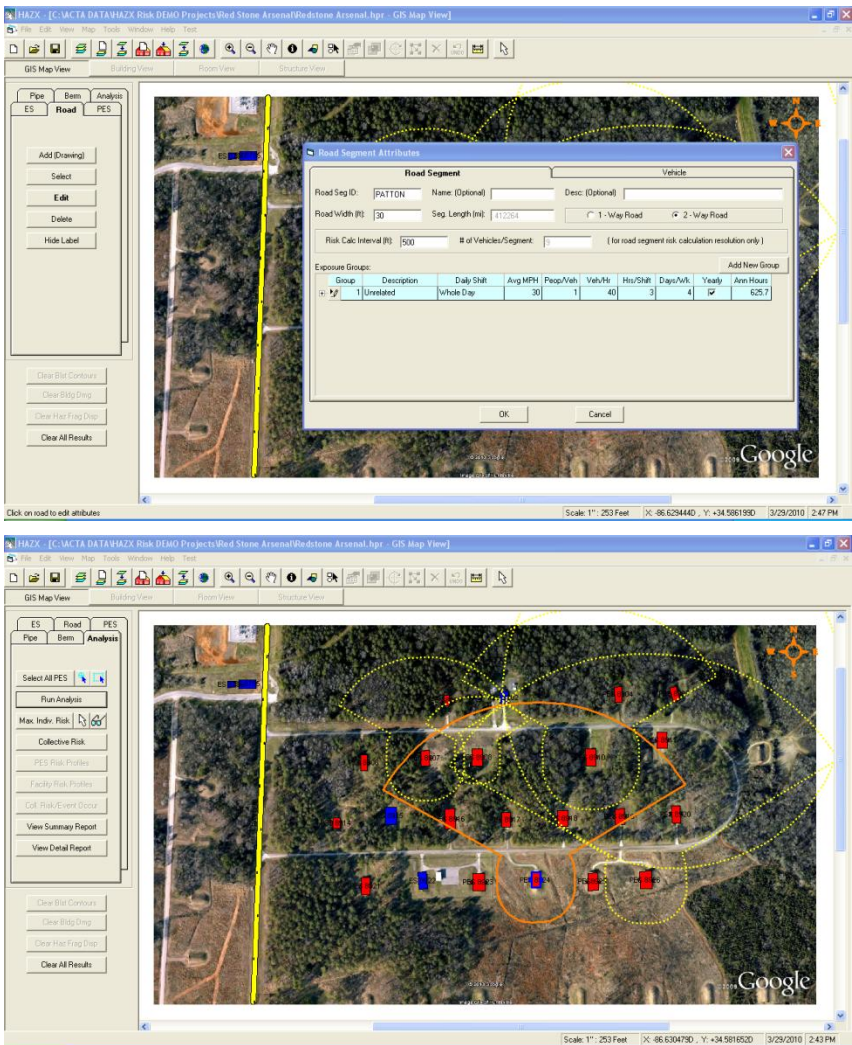
- Documentation will consist of:
  - *SDP (SW Development Plan)*
  - *SRS (SW Requirements Spec)*
  - *SDD (SW Design Document)*
  - *STP (SW Test Plan)*
  - *STR (SW Test Report)*
  - *Technical Manual*
  - *User's Manual*
- Documentation is being overseen by ACTA's V&V group at VAFB
- Security will be consistent with what is being done for SAFER
  - *Army (applying networthiness requirements)*
  - *Other services (???)*





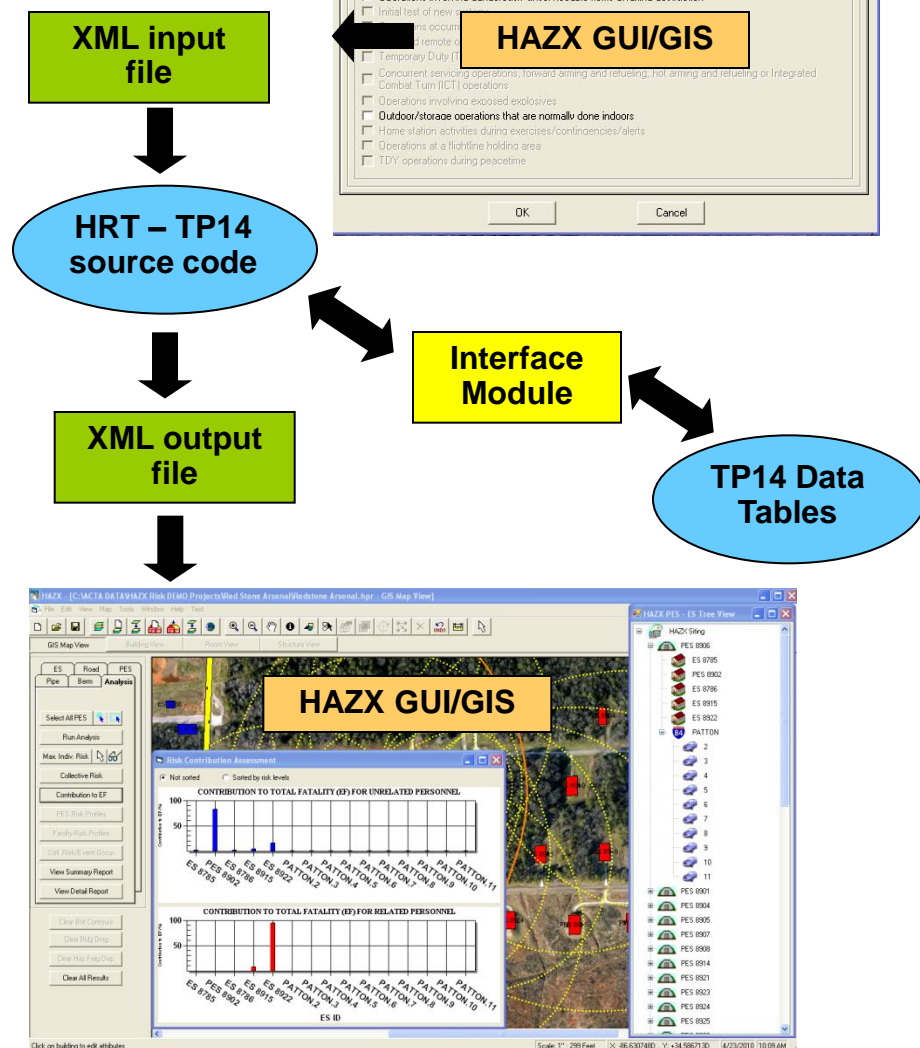
# HAZX Risk Tool (HRT) Status

- The initial HRT implements the methods in TP14 V3 to simplify cross-checking & validation before implementing improved hazard & risk models
- The HRT is being developed under a formal SW process to insure acceptable V&V evaluation
- Several paradigm shifts have been made to simplify setting up and running TP14 risk problems
  - *Eliminating most offline user calculations and decisions*
  - *Allowing visualization of results*



# Implementation of TP14 Version 3

- SAFER-like user PES & ES input screens have been implemented in the GUI when possible to ease transition for new users
- The numerous underlying TP14 data tables have been encapsulated so modifications, additions, & deletions do not affect the main source code
- The HRT accepts all inputs and outputs as standard XML files which are self-documenting and human readable
- The GIS window displays most user inputs to insure accuracy, & numerous risk outputs can be visualized





# Sample XML Input File

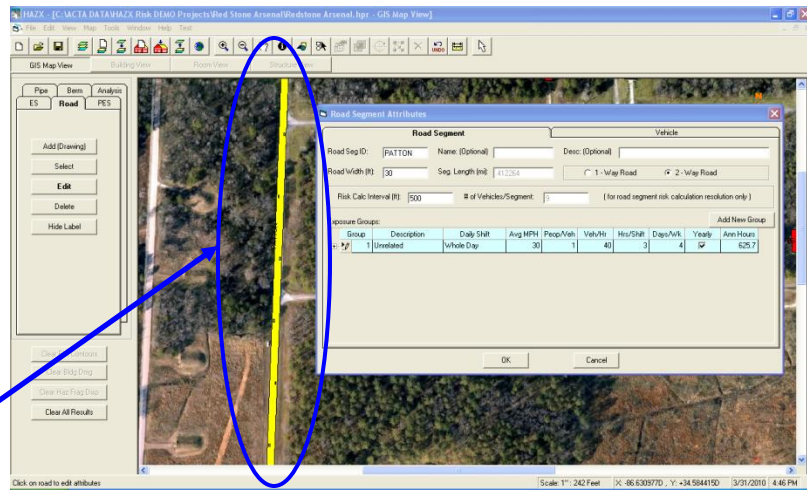
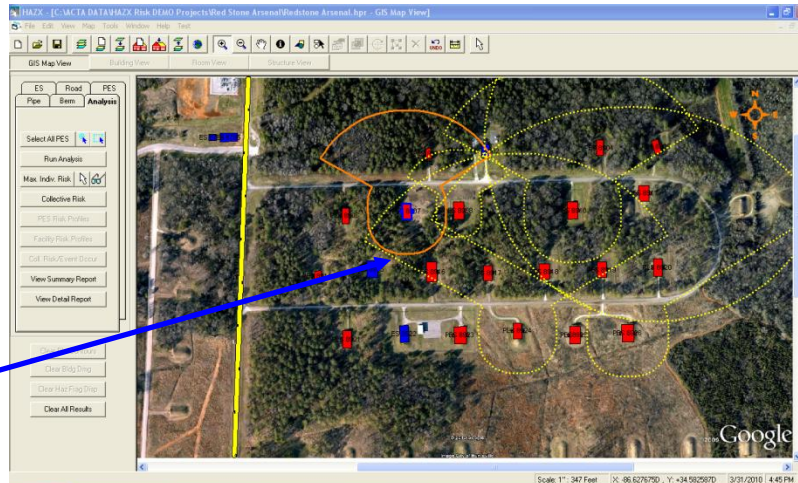
```
<?xml version="1.0" encoding="utf-8"?>
<HRT-PROBLEM-DECK unique_name="Redstone Arsenal" num_PES_total="6" enhancements="no">
  <VERSION>
    <HRT_VERSION>Phase II Prototype - 22 Apr 2010</HRT_VERSION>
    <TP14_VERSION>3.1</TP14_VERSION>
  </VERSION>
  <PROBLEM_SETUP>
    <USER>HAZX GUI</USER>
    <MODIFICATION_DATE format="mm-dd-yyyy">04-27-2010</MODIFICATION_DATE>
  </PROBLEM_SETUP>
  <PES unique_id="1" unique_name="PES 8906" num_ES_total="6">
    <PES_DETAILS>
      <SITE_DESCRIPTION>
        <Soil_type valid_list="(1-4)" tp14_step="2">3</Soil_type>
        <Building_type_code valid_list="(0-19)" tp14_step="2">7</Building_type_code>
        <Num_iso_containers valid_list="(-1,1,2,...)" tp14_step="14">0</Num_iso_containers>
        <Activity_type_code valid_list="(1-21)" tp14_step="2">18</Activity_type_code>
        <Environmental_factor valid_list="(1,3,10)" tp14_step="2">1</Environmental_factor>
        <PES_annual_operating_hours units="hr" tp14_step="2">159.428571428571</PES_annual_operating_hours>
      </SITE_DESCRIPTION>
      <EXPLOSIVE_DESCRIPTION>
        <NEWQD_sited units="lbs" tp14_step="1">7537</NEWQD_sited>
        <NEWQD_expected units="lbs" tp14_step="1">7537</NEWQD_expected>
        <Hazard_division valid_list="(1.1,1.21,1.22,1.23,1.3,1.4,1.5,1.6)" tp14_step="1">1.2.1</Hazard_division>
        <Weapon_type_code valid_list="(-1,1,2,3,4,5,6,7,8)" tp14_step="1">7</Weapon_type_code>
        <Weapon_description_code valid_list="(-1,1,2,3,4,5,6,7,8)" tp14_step="1">7</Weapon_description_code>
        <IBD tp14_step="2">1045</IBD>
        <Compatibility_group valid_list="(0,1,2,3)" tp14_step="2">3</Compatibility_group>
      </EXPLOSIVE_DESCRIPTION>
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    </PES_DETAILS>
    <ES unique_id="1" unique_name="ES 8785" tp14_step="3">
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        <ES_building_cat_code valid_list="(1-8)">4</ES_building_cat_code>
        <ES_roof_type_code>5</ES_roof_type_code>
        <ES_glass_type_code>3</ES_glass_type_code>
        <ES_percent_glass>10</ES_percent_glass>
      </ES_DETAILS>
      <GEOMETRY>
        <ES_floor_area units="ft2" tp14_var="FA_ES">5100</ES_floor_area>
        <ES_PES_orientation valid_list="(1,2,3)">2</ES_PES_orientation>
      </GEOMETRY>
    </ES>
  </PES>
</HRT-PROBLEM-DECK>
```





# HAZX Risk Tool (HRT) Paradigm Shifts (Part 1)

- The HAZX HRT GUI/GIS is utilized for all user inputs
  - User entries can therefore be visualized/validated via the GIS
  - ES's only need to be entered once
  - All required spatial measurements are made by the GIS ensuring accuracy & eliminating offline calculations
  - IBD values are based on NFESC's ESS validated QD-Engine
    - The controlling Hazard Division for each PES can be automatically calculated
    - Or, the user can over-ride and set the PES's HD
  - Calendars are used to enter the PES operating times and the ES exposure schedule
    - Therefore, the % time an ES is exposed to each PES is automatically calculated (no offline calcs are required by a user)
  - Roads (straight or curved) are entered by drawing in the segments
  - Barriers are drawn in as polygons

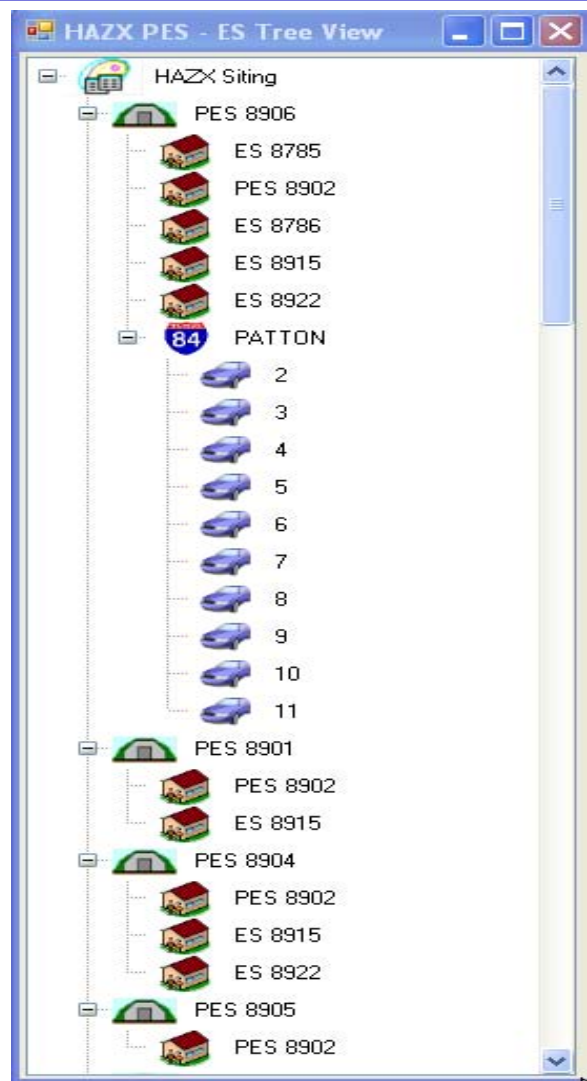
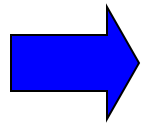






# HAZX Risk Tool (HRT) Paradigm Shifts (Part 2)

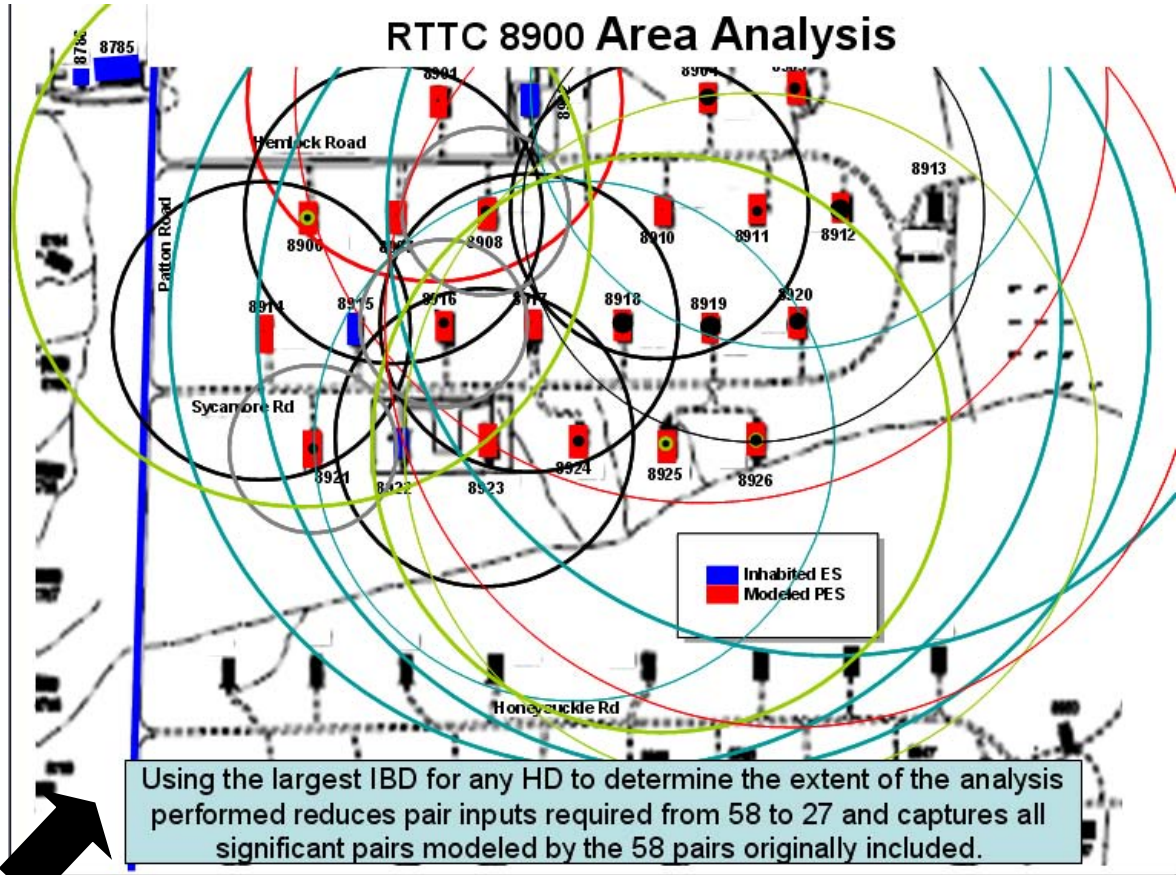
- ! – *The PES-ES tree required for a risk analysis is automatically created by HAZX (not by the user). Because of this,*
  - User errors are eliminated
  - Performing sensitivity analyses become straightforward
    - PES's & ES's can be moved/added/rotated, PES/ES attributes can be changed and new analyses performed automatically
- ! – *Various risk results are displayed in reports, charts and via the GIS to give the user critical insights into the final and intermediate results*





# Demonstration Problem

- This siting problem was brought forth by Michelle Crull as one that was difficult to set up correctly and make the appropriate “PES Siting” risk runs



Ref: Group Risk Example Case: Redstone Test Center (RTC) Area 8900 - Bob Baker, 10 December 2009



# Redstone Arsenal Problem Issues

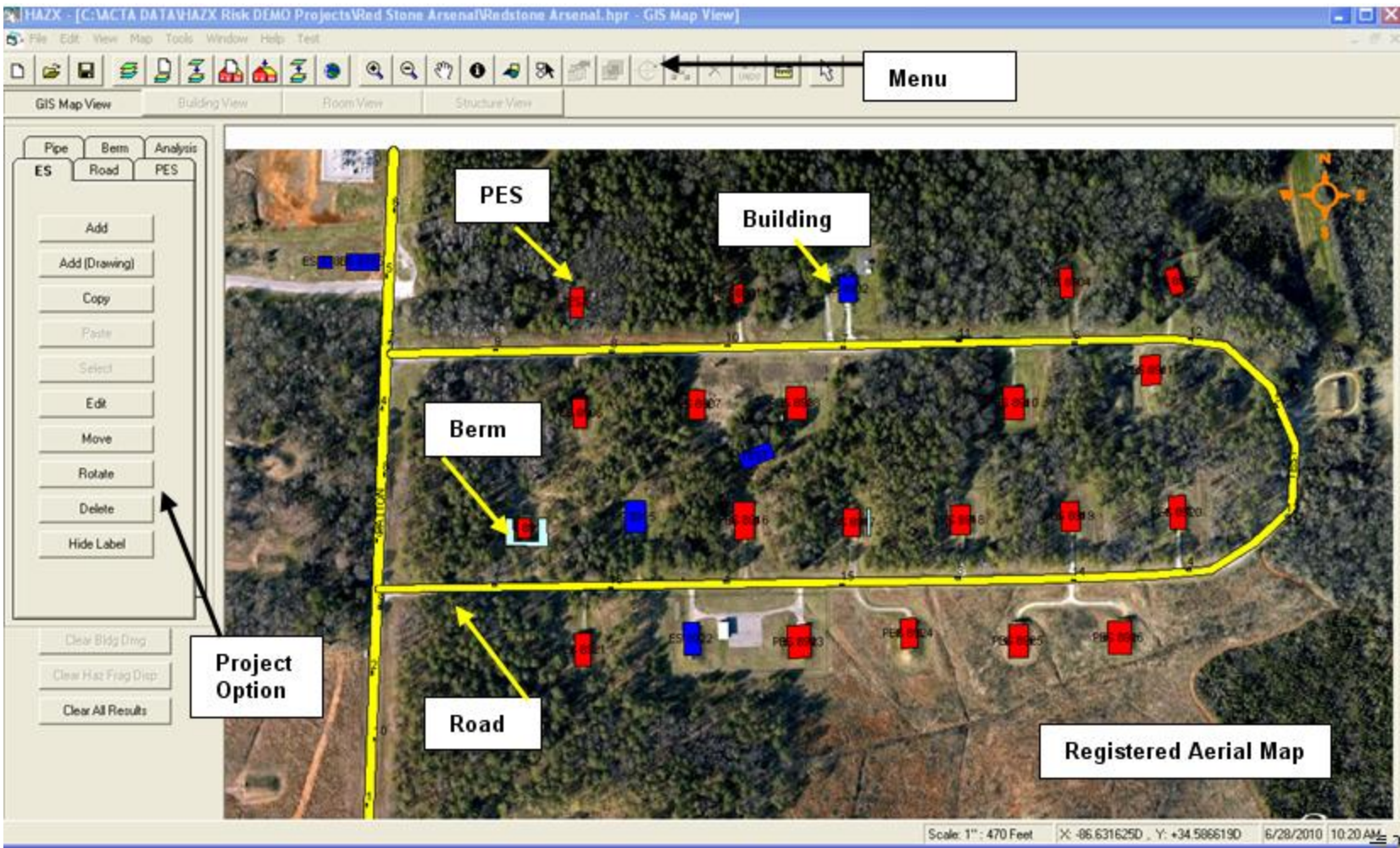
- Multiple PES's and ES's
  - *Which ones should be included in the analysis?*
- Multiple hazard divisions for each PES
  - *Which one's control the risk analysis?*
- The proper PES-ES tree for a "PES Siting Analysis"?
  - *Has the tree been input correctly?*
  - *Have the PES/ES inputs been verified?*
    - E.g., PES-ES distances
  - *Have the correct IBD's been input for multiple hazard divisions ?*
- Sensitivity analyses?
  - *Do the PES-ES tree, PES & ES attributes, etc. need to be manually updated?*
- Interpretation of results?
  - *How does the user assess the results to determine the greatest contributors to risk?*

**The HAZX Risk Tool  
architecture resolves all of  
these issues**





# Overview of Demonstration Problem

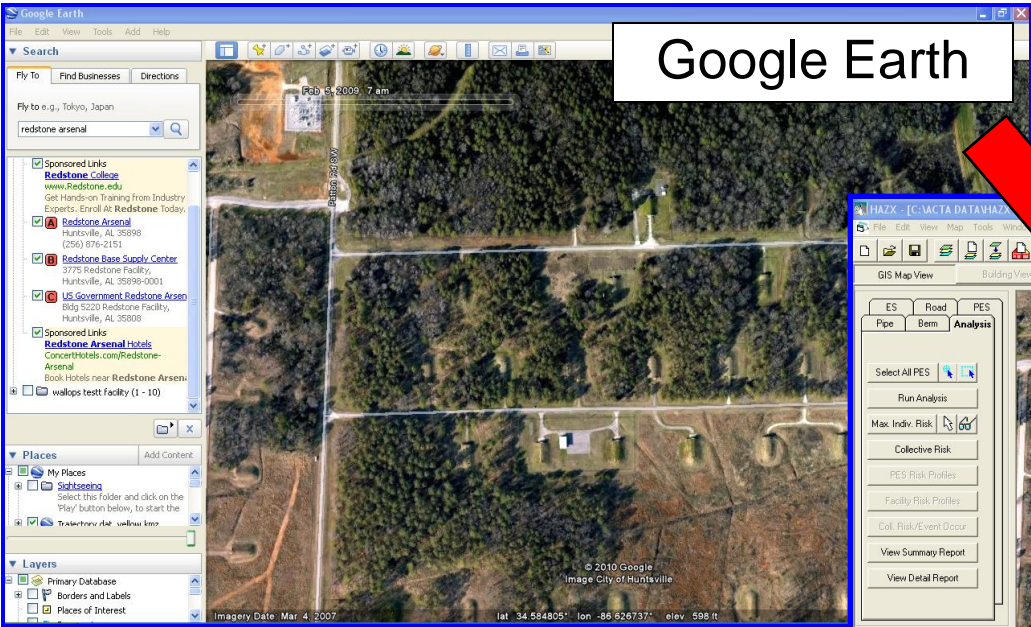




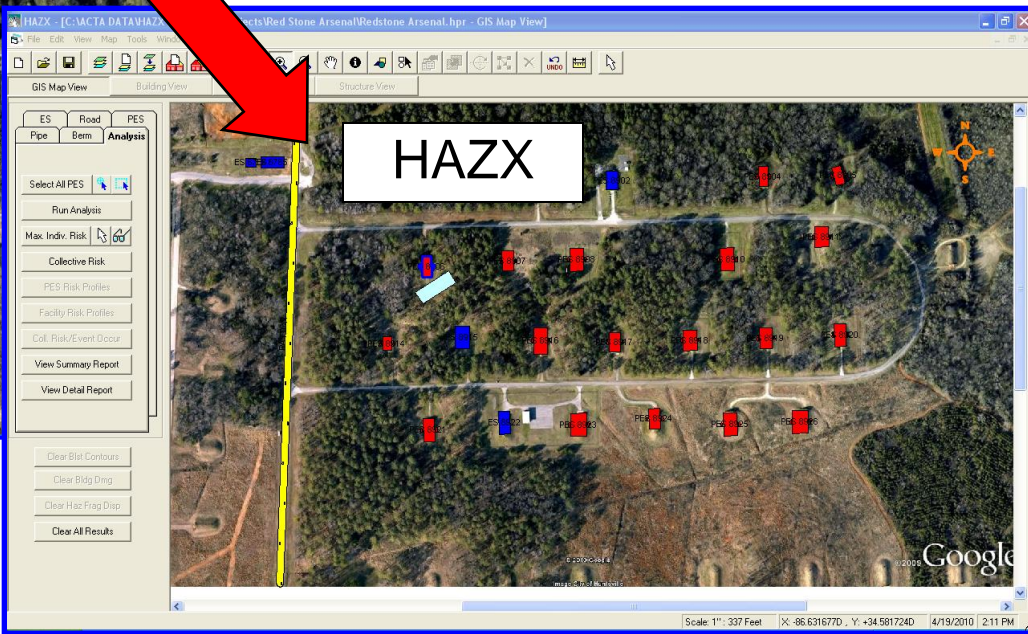


# Sample Problem (Import a Base Map)

- Aerial views & maps can be automatically imported from other applications
- Bitmaps, JPEGs, etc. images can also be manually registered if necessary
- All PESs, ESs, Roads, Barricades & their attributes can be entered via the GUI/GIS



Views could come from other tools such as MS Virtual Earth, ArcGIS Explorer, etc.



Or, maps/images can be manually registered if desired

**ACTA Inc**





# Entering ES's (Buildings)

Building Attributes

Building Information

Bldg ID: ES 8922

Bldg Name: (Optional)

Bldg Desc: (Optional)

Bldg Category: Reinforced concrete

Bldg Type: Small Reinforced Concrete (Office/Commercial)

Roof Type: 4 in reinforced concrete

Length (Feet): 50 (distance from

Width (Feet): 100 (distance from

Height (Feet): 12

Azimuth(Deg): 357 (from north to

Plan Area: 5000 ( Sq. Ft. )

Exposure

Related PES

☐ PES 8901

☐ PES 8904

☐ PES 8905

☐ PES 8906

☐ PES 8907

☒ PES 8908

Building Attributes

Building Information

Exposure Groups:

Group	Description	Type	People	Daily Shift	Hrs/Shift	Days/Wk	Yearly	Ann Hours
1	Related Personnel	Related	6	Whole Day	24	2	<input type="checkbox"/>	212.6
<div>Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec</div> <div><input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></div>								
2	Unrelated Personnel	Unrelated	10	Day Shift	8	5	<input type="checkbox"/>	1908.6
<div>Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec</div> <div><input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/></div>								

Calendar Paradigm

Clear Haz Frag Disp

Clear All Results

OK

Cancel



# Entering Roads

Road Segment Attributes

Road Segment

Vehicle

Road Seg ID: ROAD 2

Name: (Optional)

Desc: (Optional)

Road Width (ft): 25

Seg. Length (mi): 1.120875

1 - Way Road

2 - Way Road

Risk Calc Interval (ft): 700

Exposure Groups:

Group	Description
1	test

Clear All Results

Road Segment Attributes

Road Segment

Vehicle

Vehicle Length : 14 (ft)

Width (ft): 5 (ft)

Height (ft): 5 (ft)

Window Type : Tempered

% Glass: 0

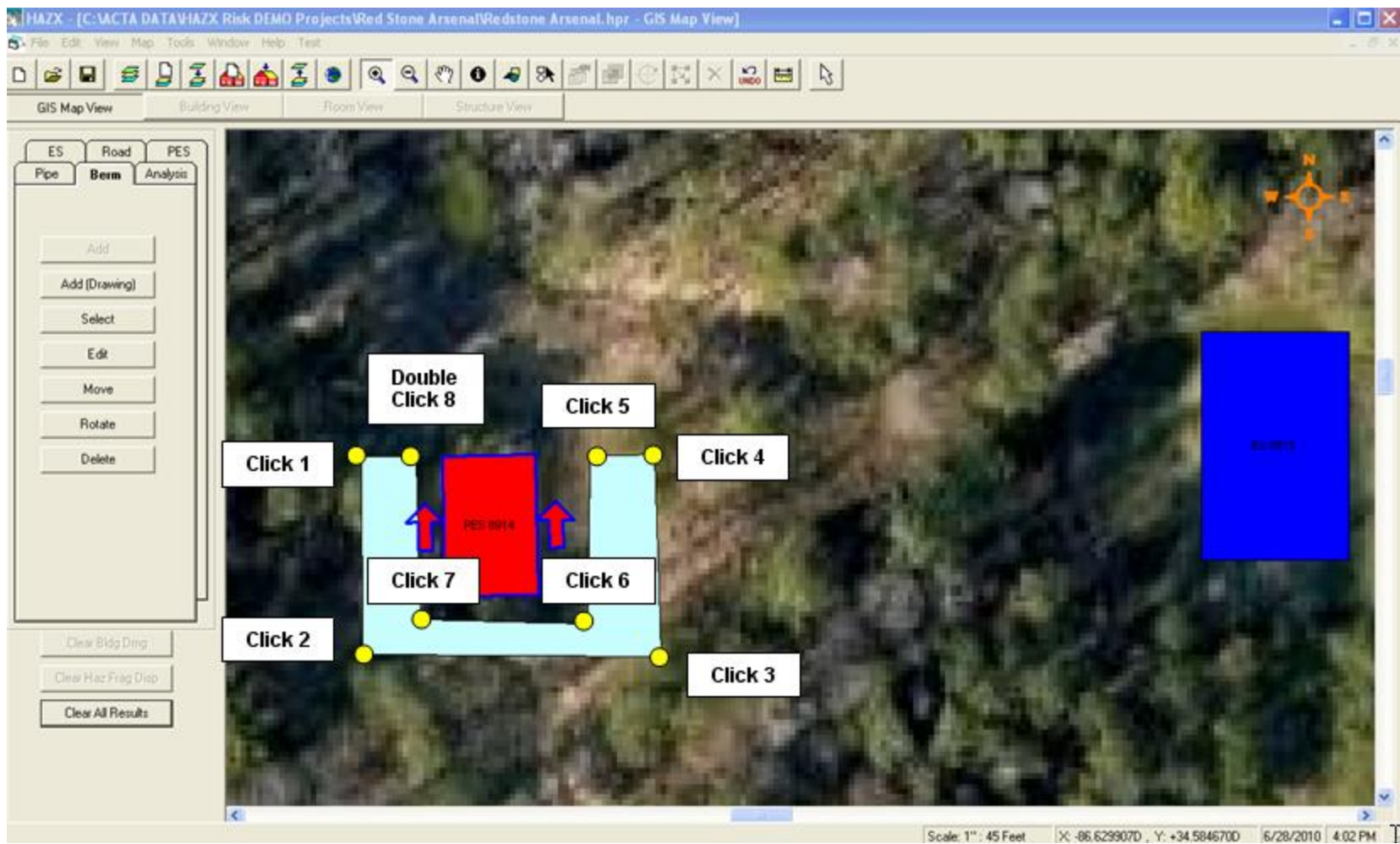
OK

Cancel





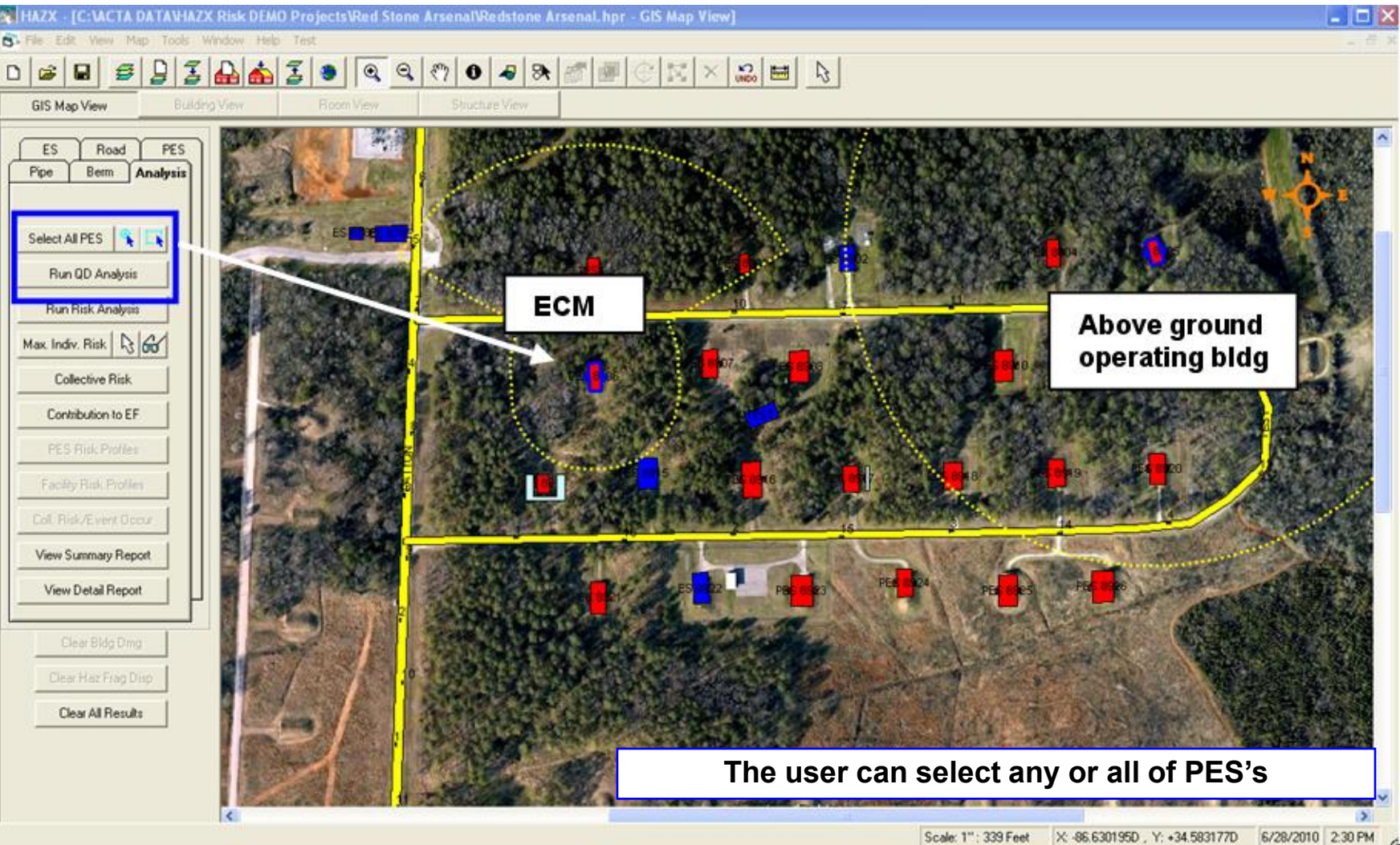
# Entering a Barrier





# Q-D IBD Analysis

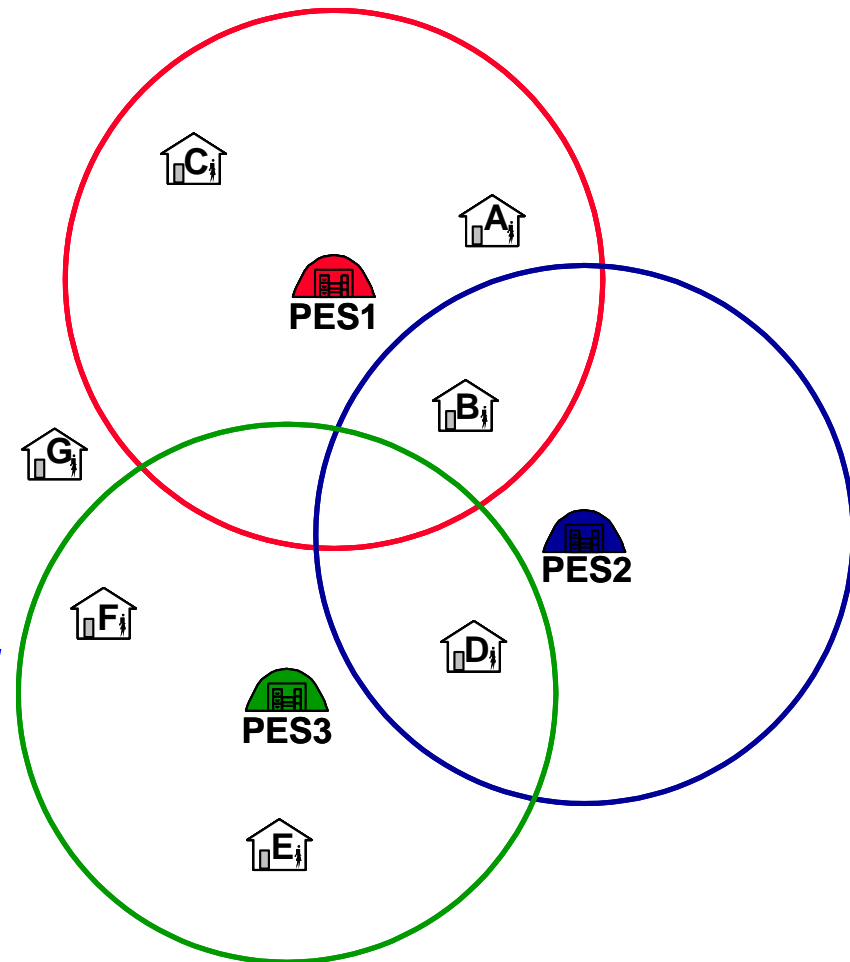
*(based on NFESC's ESS Q-D Engine)*





# PES Siting Analysis

- 1) The ES's affected by each PES are determined as follows:
  - *The controlling HD IBD Q-D arc (the largest IBD for any hazard division) is computed.*
  - *The controlling HD distance to a maximum individual probability of fatality of  $P_f < 1.0E-08$  for people in the open is calculated.*
  - *The ES's within the union of the distances computed in a) and b) are the ones that will be affected by the PES.*
- 2) The same procedure is performed for all other PES's.
- 3) The PES-ES Tree is constructed based on 1) and 2).

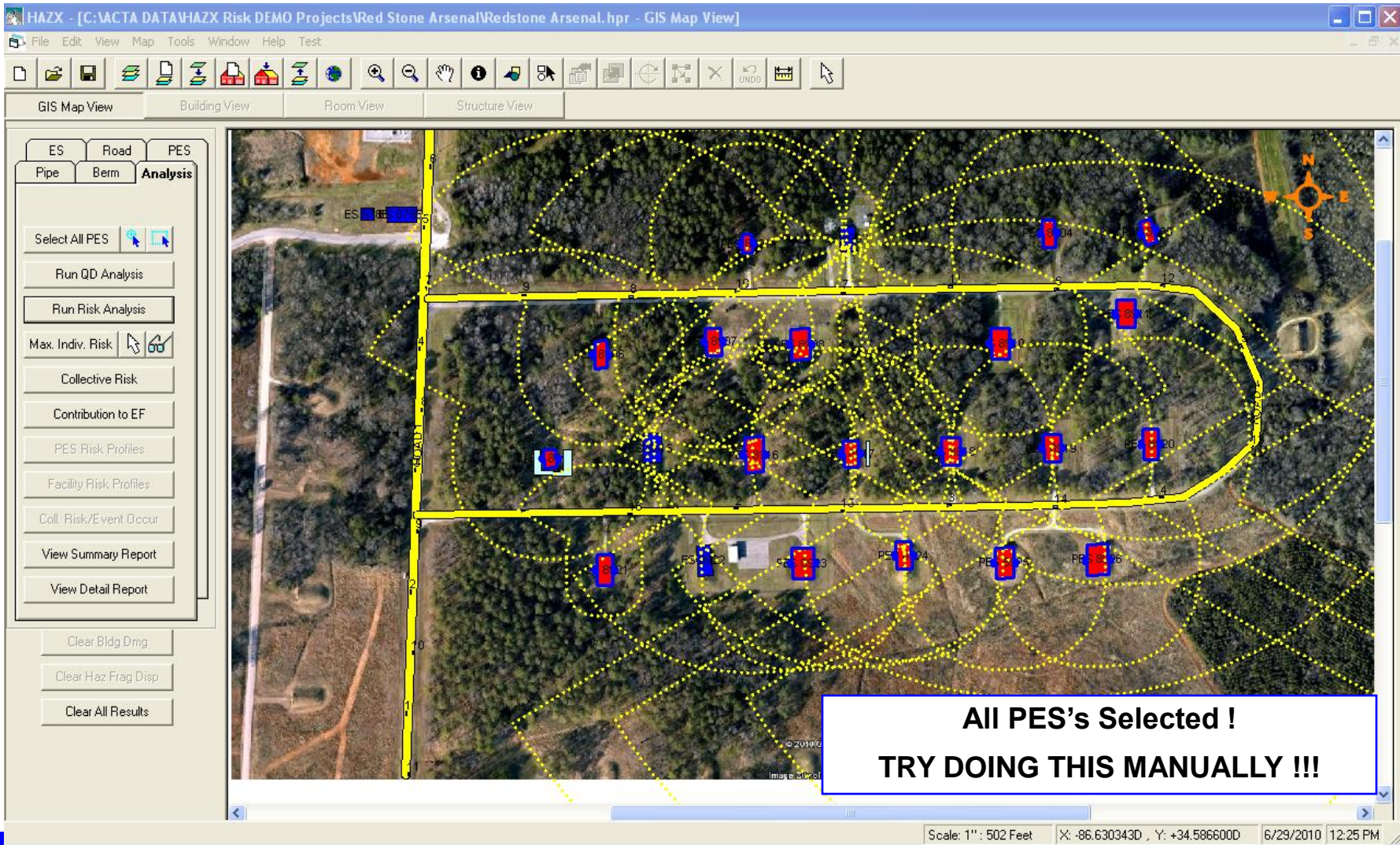






# Q-D Analysis for Example Problem

(Automated by HRT GIS Spatial Analysis & NFESC Q-D Engine)



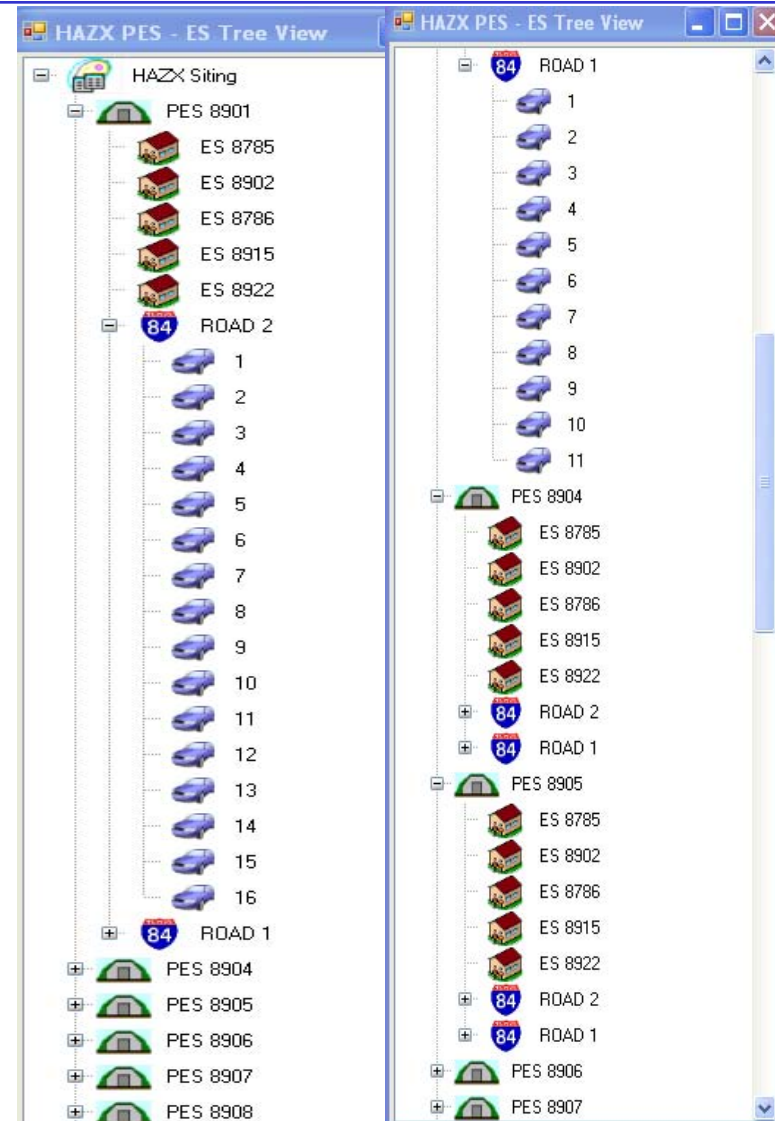


# PES Siting Analysis

## Partial Sample of PES-ES Tree

Try doing this manually !!!


- The tree is quite large due to the inclusion of the PES facility road (which would not be considered public except for our example)
- Once the tree is generated a TP14 risk analysis is performed for all PES-ES combinations
  - *Maximum individual and collective risks are computed*
- Note that other types of risk analyses can be performed
  - *Single PES-ES pair*
  - *Full-up installation risk (all PES's affecting all ES's)*





# Risk Results

- The HRT displays key risk results for the user
  - *Table comparing calculated risk vs. DDESB criteria*
  - *Maximum individual risk by ES*
  - *PES-ES pair with highest individual risk*

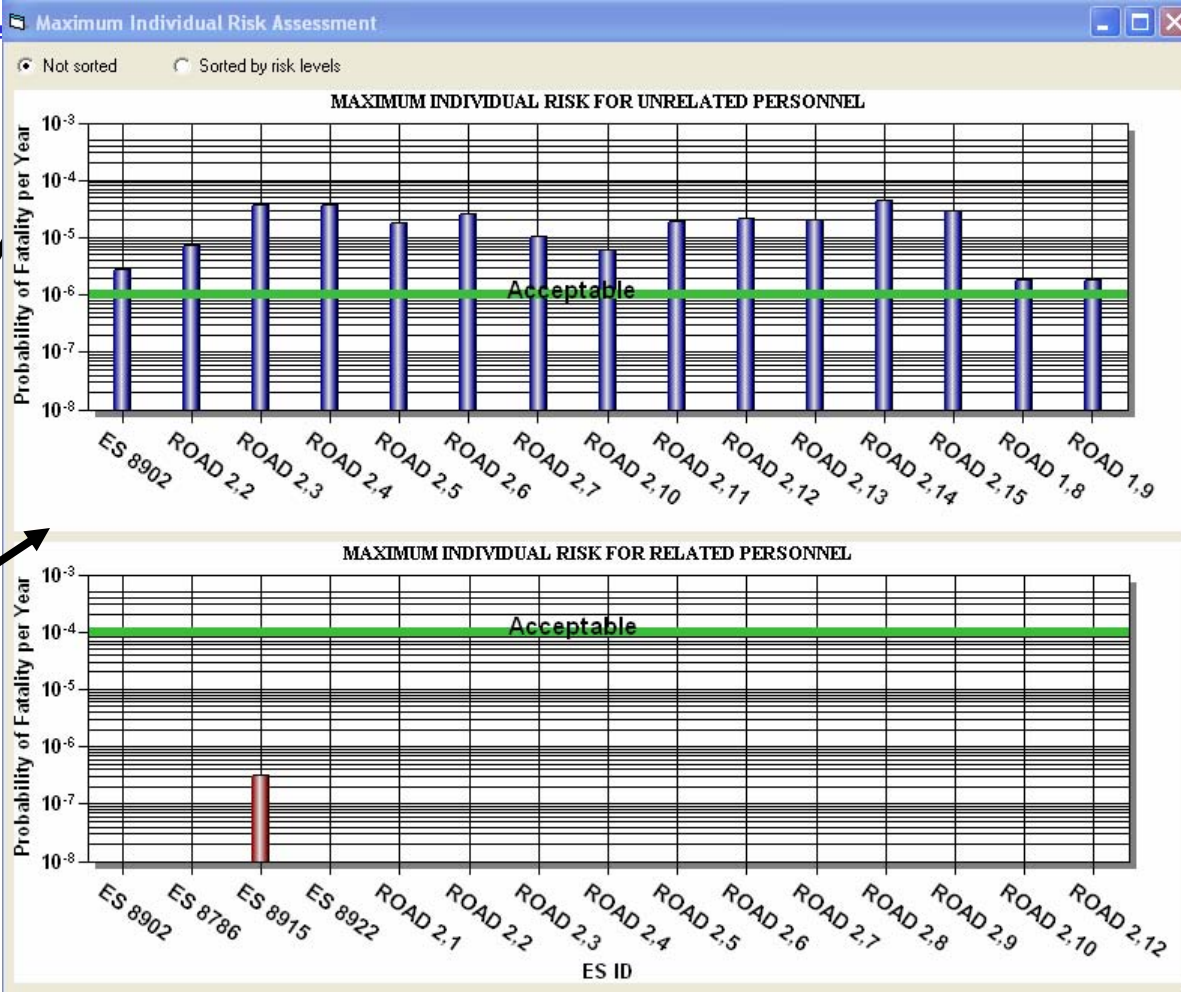


Risk Metric	Population Group	HAZX Risk (per year)	Acceptance Criteria (per year)
Max Individual Fatality	Unrelated	4.27E-05 (ROAD 2,14)	1.00E-06
	Related	3.02E-07 (ES 8915)	1.00E-04
Group Fatality	Unrelated	2.19E-05	1.00E-05
	Related	1.21E-06	1.00E-03

# Risk Results

- The HRT displays key risk results for the user
  - Table comparing calculated risk vs. DDESB criteria
  - Maximum individual risk by ES
  - PES-ES pair with highest individual risk

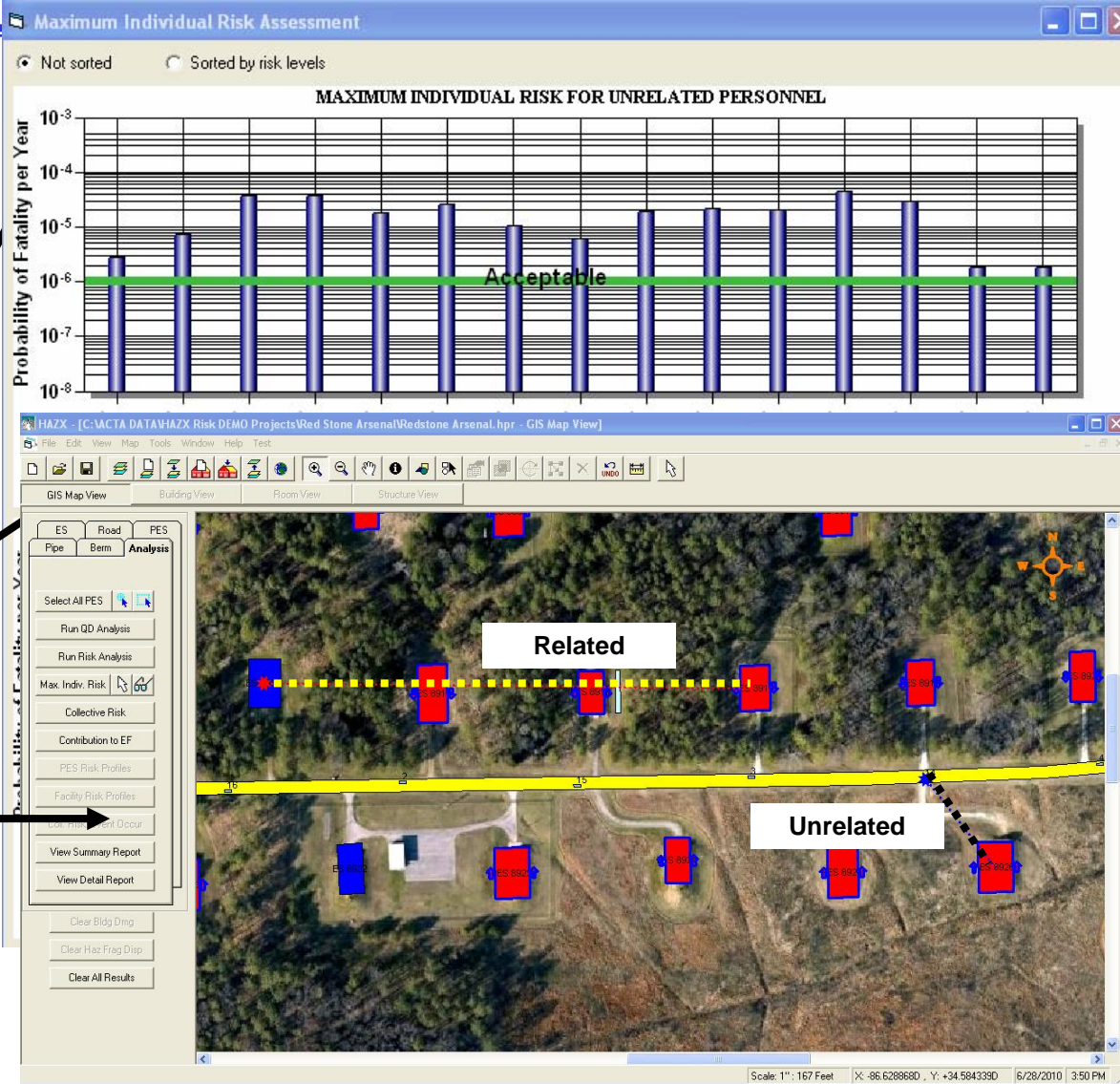
Risk Metric	Population Group	HAZX Risk (per year)	Acceptance Criteria (per year)
Maximum individual risk	Unrelated	4.27E-05 (ROAD 2.14)	1.00E-06



# Risk Results

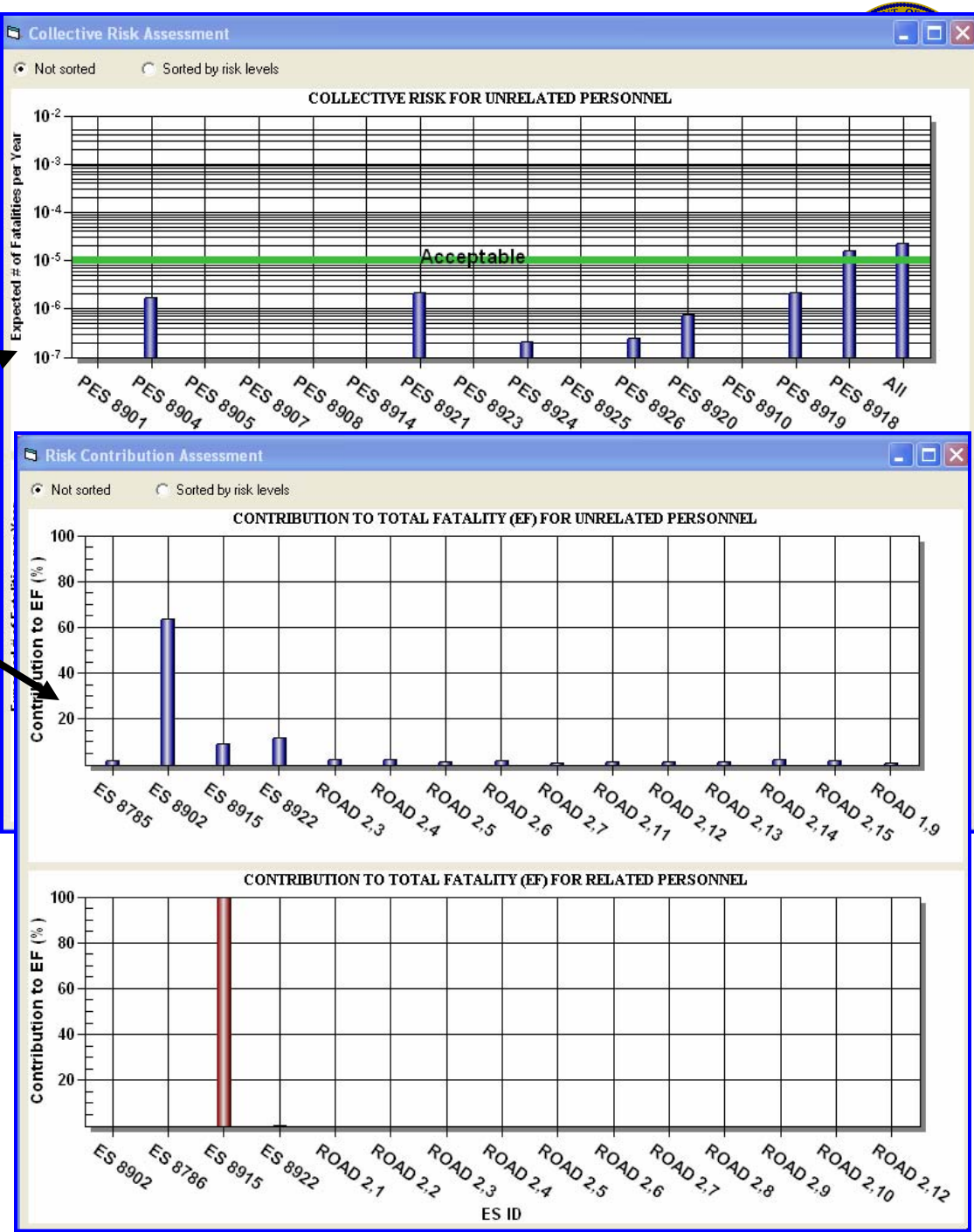
- The HRT displays key risk results for the user
  - *Table comparing calculated risk vs. DDESB criteria*
  - *Maximum individual risk by ES*
  - *PES-ES pair with highest individual risk*

Risk Metric	Population Group	HAZX Risk (per year)	Acceptance Criteria (per year)
Maximum Individual Risk	Unrelated	4.27E-05 (ROAD 2.14)	1.00E-06



# Risk Results

- *Collective risks by PES*
- *Contribution of each ES to overall collective risk*
- *Other Results*
  - Summary report
  - Detailed report w/ all intermediate results
- *Additional displays & reports are in the works*







# Conclusions & Recommendations

- The HAZX HRT is a powerful tool for performing explosives quantitative risk analyses
- The GUI/GIS provides a robust tool for setting up and performing complex risk-based analyses
- The HRT is currently based on DDESB TP14 but will eventually incorporate upgraded models
  - *uncertainty, air blast consequences, fragment/debris throw, roof/wall penetration, human vulnerability, etc.*
- DDESB approval of the HRT will be sought for use as an alternative tool
- HAZX and the HRT will be available to all DOD government agencies when officially released

